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Reconstructing Columbus's First Transatlantic Track and Landfall Using Climatological Winds and Currents

by

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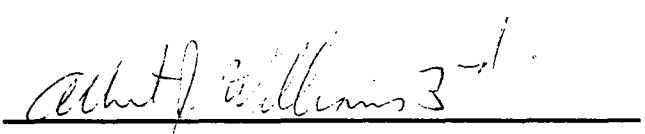

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Abstract

An article in the November 1986 *National Geographic* magazine examined the question of Columbus's first landfall in the Americas. The author, Luis Marden, was the first to quantitatively include the effects of the winds and currents in reconstructing the transoceanic portion of the voyage. There seemed, however, to be two major weaknesses in his analysis. First, the leeway effect on the ship by the wind was ignored for that portion of the voyage west of 40W, the whole second half of the voyage. Second, currents from pilot charts were used with the corresponding speed determined by the prevailing current. We sought to reanalyze the track using the leeway effect for the whole transatlantic track and using more appropriate average vector velocities of the current. Using climatological winds and currents we found the island of San Salvador (Watling Island) to be the most likely site of the first landfall of Columbus. This paper discusses the effects of wind, current, leeway, and magnetic variation on the determination of the landfall.

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Introduction

The publication of articles by Luis Marden and Joseph Judge in the November 1986 National Geographic renewed interest in Columbus's first voyage to the New World. This interest will no doubt heighten in the coming years as 1992 will mark the 500th anniversary of the European rediscovery of the Americas. It is surprising that 500 years after Columbus's first arrival in the Bahamas the precise landfall is still under considerable debate.

Several investigators before Marden have attempted to reconstruct the initial voyage of Columbus to determine the site of the first landfall. For almost 100 years geographers have proposed landfalls ranging from Turk Island in the southeast to Egg Island in the northwest of the Bahama Islands. San Salvador has been favored by researchers such as R.T. Gould, S.E. Morison, and J.W. McElroy. In addition to their recomputation of the transoceanic track, Marden and Judge backtracked from Columbus's description of subsequent landfalls. Their treatment differs from that of previous investigators, such as McElroy [1941], by applying the effects of current and leeway to the course recorded in Columbus's log. Marden's analysis indicates modern day Samana Cay as the probable first landfall. The evidence is not conclusive however. The backtracking analysis is still largely subjective, the extant copies of Columbus's log are ambiguous, and the winds and currents used in the analysis are inappropriate.

Scientists at the Woods Hole Oceanographic Institution (WHOI) have long dealt with the currents and atmospheric conditions which affect the world oceans. Data for current and wind that would affect a sailing voyage like Columbus's are readily available, actively studied, and continually refined. This information could be used to corroborate or refine the work already done, particularily as it applied to the transoceanic portion of his voyage.

This paper will look at the effects of the magnetic variation, atmospheric wind, and ocean currents as the major factors in the determination of Columbus's track. Some of the smaller effects of time and track determination, perhaps overlooked or ignored in previous studies, will also be included.

Columbus's log and course

Columbus departed Spain in the late summer of 1492 and proceeded to the Canary Islands. He spent several days there, provisioning his three vessels and waiting for favorable conditions. Leaving Gomera the morning of 06 September (by the Julian calendar) he was almost immediately becalmed, and remained for two days in San Sebastian roads, the straits between Gomera and Tenerife. Then, on the morning of 08 September, the renewal of the northwest tradewinds allowed him to begin his transatlantic voyage. Columbus himself was aboard the *Santa Maria*, the largest ship of his fleet. The positions recorded in his diary are presumed to be those of his flagship, for the captains of the other vessels, in their search for a landfall, did not always remain within hailing distance of the Santa Maria. The record of the voyage comes from a copy of Columbus's log made by Las Casas; the original log which Columbus kept has long been lost.

At the western end of Columbus's voyage the names associated with the landmarks of his era have become confused. The island of landfall was originally known as Guahanani by the natives who lived there. Which island this is today is the object of investigation. Two prime contenders proposed in previous studies are Watling Island and Atwood Island, also known as San Salvador and Samana Cay respectively. There are, then, still many ambiguities associated with the identification of the first landfall.

Even though the course sailed by Columbus is well known from copies of his log, the resulting track positions are not as equally well understood or agreed on by the many investigators. The first uncertainty is where his actual position was when he started to make headway on the night of 07-08 September. Columbus had already been sailing or drifting in very light wind for two days, so the exact position at the start time is not precisely known. The start time was taken as 0300 on the morning of Saturday, 08 September, 1492 [see McElroy, 1941]. The time of 0300 on the morning of 09 September, as stated in the text of the Judge and Marden article seems to be a misprint. To have the voyage starting then is not consistent with the log entries and leads to unreasonable sailing speeds for the first watch. For the purpose of comparison with previous studies, the start position used in this study was taken from McElroy [1941] as 28.005N, 16.992W.

The questions surrounding the use of compass headings and the actual distance in a league have not yet been fully resolved. The basic facts regarding the distance and bearing of Columbus's course legs were taken from

the translation of his diary. The version of the log used [Marden, 1986b] in our analysis is shown in Table 1a. This differs slightly from the course given by Marden, Table 1b, in that we have given those portions of days sailed on a different heading, their due weight rather than averaging over the 24 hour day. The compass headings indicate Columbus used a 32 point compass card. This would have divided up the 360 degrees of the compass into bearing points 11.25 degrees apart. If Columbus steered, or reported the heading, to the nearest compass point, a maximum error of 5.625 degrees in course heading might reasonably be expected. As his heading was usually due west by the compass, the actual error was probably considerably smaller. Apparently Columbus did not attempt to correct for the magnetic variation, certainly not in the western half of the voyage where the variation was not previously known. Until the original diary is discovered, it will have to be assumed that errors in the reported heading are random in nature and their cumulative effects will cancel one another. The distance of the Spanish and Portuguese league was recently rediscovered by Marden [1986] to be 2.819 nautical miles per league; that value was used in this study.

Some discrepancies were encountered in the translation and interpretation of the diary by various investigators. Most notable is the difference in distance sailed on 23 September; McElroy [1941] gives a distance of 22 leagues (62 km) while Marden [1986b] uses the value of 27 leagues (76 km). The latter value was used in this analysis, although an attempt was made to preserve the changes in course heading as stated in the log entry for this day.

Two additional factors which do not seem to have been dealt with in previous studies have been included in this analysis. The first is Columbus's method of determining speed. Although the speed of vessels in Columbus's day was usually determined by a log chip, Columbus relied on his own estimate of ship speed. The accuracy of his estimations would depend on his knowledge of the conditions such as sea state and wind as well as that of his vessel and crew. When Columbus was forced to spend a period of time "wearing ship", or changing course, his reckoning of actual headway could only be the result of his computation of the projections of the various legs along his intended path.

Further, the distance and bearing were usually summarized for a whole watch. The "day" watch for this voyage was determined from a period starting about sunrise and ending at sunset. As the vessel track was not far from the earth's equator and occured at the time of the autumnal equinox,

sunrise was taken to be about 6 am (0600) for this study. The "night" watch likewise began at sunset or about 6 pm (1800), and would continue until the morning of the next day. As all times were local, depending on the sun position, there was a small but significant gain of time as Columbus sailed west. Over the course of the 34 day voyage this amounted to an approximate 0.5 percent increase in the "daily" sailing time. McElroy [1941] thought that Columbus was aware of the noon to noon time being more than 24 hours, but gives no indication of his allowing for it in the computation of distance made good. The analysis presented here will show the effect of this day lengthening in the reconstructed course.

The second factor also relates to time, in this case the season of the voyage. Columbus started to make headway on the morning of 08 September, a date recorded using the convention of the Julian calendar then in effect. The Gregorian calendar system currently in use for most of the world was implemented in 1582 when Pope Gregory decreed that the day following 04 October 1582 should become 15 October 1582. This was done because the Julian calendar had become out of step with the actual seasons and solstices by ten days. Thus, by the modern calendar, the voyage of Columbus actually occured later in the solar season. Because the voyage took place 90 years before the adoption of the Gregorian calendar, the dates in the diary have been modified by adding nine days. This fact is used in the determination of the correct seasonal factors, such as wind and currents, in the analysis which follows. All summaries will be listed with the Julian dates used by Columbus.

Magnetic corrections

The effects of the magnetic pole offset from true north must first be considered. When Columbus sailed on a course due west by the compass he was actually traveling west only with respect to the local magnetic field. Further, the magnetic pole was not in the same position in 1492 as it is now. The deviations from true north must be taken into account to determine the actual geographic locations visited by the vessel *Santa Maria.*

Figure 1a shows a plot of the isogonic lines for magnetic corrections at the approximate time of the Columbus journey. These values were taken from a map published by Van Bemmelen in 1899 and shown by McElroy [1941]. Values for the corrections were taken at five degree increments, then

interpolated to a one degree grid using a bicubic polynomial algorithm. The values at the original grid nodes were preserved. McElroy used a correction of approximately -1.0 degrees in the region of the Bahamas; grid nodes in that area have been assigned values that are consistent with that interpretation and result in the smooth field shown in Figure 1a. For comparison, Figure 1b shows the modern (1980) magnetic corrections. This data set was prepared in the same manner as described above, using values taken from a chart of the North Atlantic Ocean published by the Defense Mapping Agency [1982].

Wind effects

The wind was the primary force driving Columbus's ships across the Atlantic. Columbus showed the good sense to choose the latitudinal band where the prevailing winds could generally be relied on to blow westward, the direction that he wished to sail. This allowed him to plot a direct course and make the most efficient use of the wind. Nevertheless, the wind was not always directly astern, and thus there would have been a slight slippage due to the force component of the wind acting normal, or perpendicular, to the course steered. This leeway affects every vessel, pushing it sideways through the water.

To determine the leeway requires a measure of both the wind velocity and its effect on a caravel sailing vessel of the type Columbus used on his voyage. The first portion of the track which Columbus followed, in the eastern Atlantic, is marked by the northeast trade winds. These winds are quite consistent in their direction and speed, although there are slight seasonal variations. A study at WHOI on the climate of the North Atlantic [Bunker and Goldsmith, 1979; Goldsmith and Bunker, 1979] used several million ship of opportunity meteorological observations from the period 1948 to 1972 to compute monthly climatological averages for many parameters, including the wind field. These data were further processed to generate monthly averages for the resultant winds at points centered in one degree squares [Isemer and Hasse, 1985]. The component wind fields in the region of the Columbus track were then processed using a bi-linear interpolation algorithm to reconstruct the grid on nodes every one degree. The speed was reconstructed from the vector components to produce an average wind field such as may be encountered by a vessel sailing in that region. This

procedure was performed for both the September and October data set; the resultant wind fields used in the study are shown in Figure 2. Also generated was a combined vector average of these two months, producing an autumnal wind field (Figure 4b).

The computation of a vessel's leeway is a function of the wind velocity and vessel's course, but also depends on ship design and other parameters. For this analysis the leeway was estimated and taken to be a constant 1.4 percent of the wind component normal to the ship course. This was in close agreement with the 1.5 degree leeway used by Marden [1986] in the region of the northeast tradewinds.

Current and drift

By measuring the difference between the course and the actual track made good by modern vessels, the ocean current can be measured. A large number of these observations for the years 1875 to 1976 was obtained from the Naval Oceanographic Office and analyzed to produce mean climatological current fields for the twelve months of the year. These data were vector averaged over areas 2 degrees in latitude by 5 degrees in longitude to ensure sufficient observations to provide a reliable estimate of the climatological current field in the open ocean. These monthly data sets were processed using a bilinear interpolation method to produce surface current velocities (direction and speeds) for one degree squares in the region of Columbus's track.

In the region of the Bahama Islands the currents are not nearly so uniform as in the mid Atlantic. The currents vary in both speed and direction among the many islands. Furthermore, the Gulf Stream, which passes between the Bahamas and Florida, has speeds an order of magnitude greater than those encountered in the mid Atalantic. There are also many more drift observations available in this area as it contains frequently traveled shipping lanes. Data in the western area bounded by 20N, 30N, 70W, and 80W were vector averaged by one degree squares. The resultant field was then used in the region of the Bahamas to negate any influence the Gulf Stream may have contributed in using the larger 2 x 5 degree averages (Figure 3).

The use of average currents in this analysis differs from the prevailing current speeds taken from monthly pilot charts by Marden. For those charts, the average speed appears to have been computed independently of the direction, or using only a defined primary directional subset of the total

observations available. While the currents in this region are fairly constant, vector averages over variations in the direction result in a reduced net speed over long climatological time averages. The resultant current speeds were generally found to be approximately a third of those shown in the pilot charts.

The current field used in the analysis of the Columbus voyage are shown in Figure 03. As with the wind field analysis, the monthly data sets were combined to produce an autumnal current field, shown in Figure 4a. The current field indicates that the general circulation of the Atlantic gyre was acting to carry Columbus's vessels westward, with only modest southward and northward deflections occurring at the beginning and end of the voyage respectively.

Analysis

In recreating the track followed by Columbus, the starting point was taken at 28.005N, 16.992W as determined and used by McElroy [1941]. Because the diary generally gives the heading and distance sailed for the 24 hour day or watch, these values had to be taken as a constant for the period being studied. First the heading was corrected to true geographical heading by applying the magnetic compass correction. Using this heading, and the estimate of the distance made good from the log, the velocity of the vessel was calculated.

The position of the vessel is presumed to be known at the start of the time interval and a bilinear interpolation was used to determine the wind speed and direction. When monthly average wind component fields were being used the correct Gregorian date was used to determine the corresponding September or October data set. From the computed wind the component normal to the vessel's course was determined. Multiplying this value by the leeway correction factor produced a velocity of the leeway and this was added to the vessel velocity.

In a similar manner the current velocity was determined for the ship position and added to the vector summation to obtain the vessel velocity. The distance sailed was determined by multiplying the velocity by the time sailed (over the computation interval). When the effects of the progression of local noon were being included, the time interval was multiplied by the factor 1.0046625.

Columbus used "dead reckoning" to navigate his fleet; he combined the ship's compass heading, speed, and time of run to determine his "distance made good". This may have been done as often as every one-half hour, that being the standard sand glass interval. In our analysis, his navigation was duplicated as closely as possible by recomputing a new position every one-half hour during the log interval. This reduced some of those effects which may have been introduced by the large, 24 hour time intervals in the log. The smaller time increments give a better realization of the wind and current changes implicit in the one degree squares of environmental and magnetic variation data.

The method used to compute the track positions attempts to duplicate the "rhumb line" navigation as much as possible. This was done by computing the local latitude change and then computing the corresponding change of longitude. A great circle track, as would be obtained using spherical trigonometry, changes significantly as a function of the computational time step. With a small computational time step (one half hour) a great circle track approaches the "rhumb line sailing" method in the determination of a final position for the time step. This would correspond to a helmsman continually adjusting the steering to maintain a constant heading. In reconstructing the track however, it is worth noting that if one uses the spherical trigonometry method and Columbus's log with 24 hour computation intervals, the track termination point is artificially deflected almost 0.4 degrees (44 km) southward from that obtained by using the rhumb line positioning. For the course in general, great circle solutions are positioned south of those positions produced by the rhumb line analysis used in this study. This point is very important to the analysis procedure. Columbus did not sail a great circle route, the shortest distance to the new world, in part because he did not know the actual position of his final destination.

Results

Several scenarios were run with this model, applying succesive corrections to account for each of the parameters discussed above. A general overview of the results is shown in Figure 5 and all cases are summarized in Table 2. Also included, for comparison, are the track terminations computed by McElroy [1941], and Marden [1986].

Case 1a presents the track of the course as obtained from the log. No cor-

rections have been made for magnetic variation, current, or wind. The track does not approach any land and the endpoint is well north of the general area of the Bahamas where a landfall is supposed to have occurred. Correcting for the magnetic variation that was in effect at the time of Columbus's voyage (case 1b) moves the termination of the track south southeast 310 kilometers. This is well short of any land but in the general latitude of the Bahamas and midway between two of the potential landing sites, Watling Island (San Salvador) and Samana Cay.

Adding in the effects of the currents displaces the endpoint westward about 135 kilometers, consistent with the clockwise circulation in the southern portion of the mid-Atlantic gyre. The current field used in this case was the average of the September and October fields and is referred to as "autumnal." The endpoint of the track is now in the longitudinal vicinity of the Outer Bahamas; the track terminates only 32 kilometers southeast of Watling Island. When the leeway effect of the wind is incorporated into the model, the endpoint is moved 8 kilometers northwest so that the final track termination is only about 25 kilometers southeast of Watling Island.

While none of these scenarios proves conclusively a specific landfall, they all favor a more northerly site, close to that of Watling Island. An additional point worth noting is that the last watch of the voyage has a definite northward component to the track. Columbus's last course was 270 degrees (west), but all the major elements, magnetic variation, currents, and winds, conspired to push his vessels northward during this final phase of the voyage. The magnitude and interactions of the various factors are further examined in the following figures.

Also shown in Figure 5 is the effect of the progression of local noon (case 1e). This has been shown applied to the uncorrected track (case 1a), but has also been computed for the fully corrected track and is included in the appendix as case 1f. The extra sailing time gained in the 24.00466 hour day results in an additional distance sailed, shifting the termination point approximately 25 km westward. The effect is small but not insignificant considering the distances between the islands on which Columbus might have landed. While the correction for the lengthened day is not used in the majority of the remaining scenarios the magnitude of the effect should be kept in mind.

Figure 6 shows the track endpoints using different combinations of the wind and current fields. The most remarkable feature in these scenarios is

the small variation in position. All cases result in a termination point in a region roughly 20 km by 30 km in extent, centered approximately 35 km southeast of Watling Island. The tracks reflect a little stronger wind circulation in September, resulting in more northerly velocities in the western Atlantic. The October wind field tends to be more zonal and weaker than in September. The current field reflects a similar pattern. All tracks favor a more northern site for the landfall at Watling Island.

Figure 7 shows the relative contribution of leeway and current. The effect of the current is predominantly longitudinal, reflecting the velocities of the southern portion of the Atlantic gyre. The leeway effect of the winds is shown to be small in comparison. Figure 8 shows the effect of varying the leeway factor. Increasing the leeway factor results in a greater slippage in a direction normal to the course. As the leeway factor was increased, the termination points were moved to the northwest. The effect of using different factors is not as large as that obtained from using the various wind fields shown in Figure 6. Figure 8 also illustrates the influence of the southeast trade winds in the western half of the Atlantic. These would set a vessel northward and offers good proof that Marden should not have assumed following winds (and no leeway) west of 40W.

Figure 9 shows the progressive effects of removing leeway, using a larger computation interval, and using great circle positioning. The effect of removing the leeway west of 40W results in a displacement of the termination points (from case 1d) 22 km to the southeast. Using a computation cycle equal to the time interval between log entries results in another small displacement of 9 km in the same direction (case 5c). As discussed earlier, this larger computation interval gives only coarse corrections for winds, currents, and magnetic variation. Finally, the track was computed using spherical trigonometry for great circle positioning (case 5d). The displacement 35 km to the south demonstrates the positioning errors which may accumulate, especially when using the large computation interval. The net effect of these scenarios displaces the track termination over 60 km to the south and could lead to the conclusion that Samana Cay is the landfall.

The uncertainties in the log courses can also have a significant effect on the termination point. Using the course from the casebook [Marden, 1986b] with our autumnal winds and currents and one half hour rhumb line positioning, we saw the voyage terminate 3 km east of the sourthern tip of Watling Island (case 5e).

Figure 10 shows the track from case 1d (used as the base for the variations discussed in the above figures) superimposed on the environmental fields. The most dominant of the three major factors is the magnetic variation. We used Van Bemmelen's (1899) map for compatibility with the Marden and McElroy studies. As that map is a key component of several Columbus voyage reconstructions, it deserves a closer examination. Van Bemmelen refers to a map by Gelcich (1885), and Gelcich cites Schott (1881). All three of these authors used Columbus's own observations of magnetic variation, made on his first transatlantic voyage. Columbus, or at least the extant copies of his log, provides observations relevant to the magnetic variation on only three occasions – the 13th, 17th, and 30th of September. On 13 September he logged [Morison, 1963] "This day at the beginning of night the compass needles varied to the NW, and in the morning a little to the NE." For 17 September the log read "The pilots took the North in order to mark it, and found that the compass needles varied to the NW a full point; and the mariner's took fright and were troubled and did not say why. The Admiral knew it, and ordered that the North be marked again at dawn, and they found that the needles were true. The reason was that the star appeared to move and not the needles." On 30 September he logged "Also at nightfall the compass needles varied to the NW one point and at dawn they were right on the Star, whence it appears that the Star moves like the other stars, and the needles always point true."

Thus on both 17 and 30 September the compass read at dusk one point (11.25 degrees) westerly variation and at dawn no variation. The difference in readings in the evening and morning is due to the apparent daily rotation of the North Star which, in the year 1492, was at an angular distance of about 3.5 degrees from true north. The best estimate of magnetic variation for those dates is an average of the evening and morning observations, about 5.6 degrees westerly deflection. An estimate for 13 September is more difficult to pin down because the actual variation at dusk or dawn is not explicitly stated. However, the implied average variation was nearly zero. The variation for the 1492 landfall in the Bahamas also remains uncertain; Schott (1881) concludes "the delination was very small and probably less than 1/4 point west."

Using these direct observations by Columbus, plus Van Bemmelen's value of 3.0E for the Canary Islands and Schotts estimate of 0.0 for the Bahamas, we reconstructed the field of magnetic variation along the track of the *Santa Maria* (Figure 11a). The geographic position of the vessel at the time of

the observation was based on the results obtained in our case 6d. A field of magnetic variation was computed using an algorithm which minimizes the curvature of the fitted surface. The resulting field was similar to that obtained by Van Bemmelen, but our maximum westerly variation is smaller than Van Bemmelen's and shifted to the east. The landfall scenario using this field is shifted to the north and lies right on Watling Island (case 6a).

Although the five values we used reveal the large scale distribution of the variation, no observation was made in the mid Atlantic near where the maximum westerly variation might have been located. In addition, the shape of the field in the region of the Bahamas seems to be mostly conjecture and Columbus's observations of the variation are probably accurate to no better that a few degrees. We think that the average magnetic field of 1492 along the track is known to no better than a degree or two, and thus our identification of a landfall must be tempered with caution.

An interesting sidelight of the effect of the magnetic variation is shown in Figure 11b. This scenario (case 6b) shows approximately what would happen if one tried to laboriously follow Columbus's logged courses and distances with the present magnetic field (1980). The currents and winds have been ignored since if the voyage had gone in this direction the winds and hence the vessel speeds would not have been the same as actually encountered. The resulting track, when compared to cases 1a and 1b (3a) shows how much the magnetic variation influences the termination. A landfall would have been made far to the south, near present day Antigua and Guadaloupe Islands, and would have occurred on 07 October or earlier if the generally westward currents were included in the simulation.

Conclusions

The results from this analysis give strong evidence that, when historical climatological data are used to correct the course of Columbus's voyage of discovery, the track terminates very closely to a landfall at Watling Island (San Salvador). Using vector averages for the wind and current fields is the more correct approach for reconstructing a one month voyage such as Columbus undertook. While the average speed for the current and wind may be appropriate for a short period such as a day, the speeds resulting from vector averaging give a better model of the mean field likely to be encountered over the longer periods of the voyage. It may be argued that

Columbus did not have "average" conditions, that the weather may have been anomalous. While the diary gives no record of the unusual, the very fact that the vector averaging accounts for the unusual makes it appropriate.

More importantly, use of the mean vector fields for currents and winds solves the overshoot problem encountered in previous investigations of Columbus's first landfall. Because the assumed currents based on speed alone pushed the supposed landfall far to the west, investigators have had to incorporate some type of "correction" factor, successively shortening the track until a landfall in the proper region was encountered. Use of the 2.819 nautical mile per league conversion factor and the vector averaged fields resulted in all scenario tracks terminating in the eastern edge of the Bahamas near 74W longitude.

Questions remain which could affect the results computed here. Where was the actual starting position? What were the precise headings? How accurate is our understanding of the actual 1492 magnetic variation? What was the bearing of the land when first sighted? Did the captain immediately cast anchor, or did they perhaps sail two leagues before anchoring at 2 am on the morning of 12 October? Perhaps the original diary will have to be found to answer these questions. What about the post landfall voyages? The analysis presented here considers only the transoceanic portion of the voyage. The case which Marden presents for subsequent points of contact and cross referencing are persuasive and should be carefully weighed. Finally, to verify the analysis, the methodology presented here might be extended to cover Columbus's voyage back to Spain, or subsequent crossings.

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Tables

Table 01a:

Course of Columbus used in study, based on Diary (see Marden, 1986)
Starting position: 28.005N 16.992W (see McElroy, 1941)
Starting time: 08 Sep 0300h

Watch ending Date	Time	Compass Bearing	Leagues Sailed	Nautical miles	kilo-meters	Speed knots
09 Sep	0600	270.0	9.0	25.37	47.0	0.94
10 Sep	0600	270.0	45.0	126.86	234.9	5.29
11 Sep	0600	270.0	60.0	169.14	313.2	7.05
12 Sep	0600	270.0	40.0	112.76	208.8	4.70
13 Sep	0600	270.0	33.0	93.03	172.3	3.88
14 Sep	0600	270.0	33.0	93.03	172.3	3.88
15 Sep	0600	270.0	20.0	56.38	104.4	2.35
16 Sep	0600	270.0	27.0	76.11	141.0	3.17
17 Sep	0600	270.0	39.0	109.94	203.6	4.58
18 Sep	0600	270.0	50.0	140.95	261.0	5.87
19 Sep	0600	270.0	55.0	155.04	287.1	6.46
20 Sep	0600	270.0	25.0	70.47	130.5	2.94
20 Sep	1800	281.2	3.8	10.71	19.8	0.89
21 Sep	0600	292.5	3.8	10.71	19.8	0.89
22 Sep	0600	270.0	13.0	36.65	67.9	1.53
23 Sep	0600	292.5	30.0	84.57	156.6	3.52
23 Sep	1800	315.0	13.5	38.06	70.5	3.17
24 Sep	0100	326.2	8.1	22.83	42.3	3.26
24 Sep	0600	270.0	5.4	15.22	28.2	3.04
25 Sep	0600	270.0	14.5	40.88	75.7	1.70
25 Sep	1800	270.0	4.5	12.69	23.5	1.06
26 Sep	0600	225.0	17.0	47.92	88.8	3.99
26 Sep	1500	270.0	11.6	32.70	60.6	3.63
27 Sep	0600	225.0	19.4	54.69	101.3	3.65
28 Sep	0600	270.0	24.0	67.66	125.3	2.82
29 Sep	0600	270.0	14.0	39.47	73.1	1.64
30 Sep	0600	270.0	24.0	67.66	125.3	2.82
01 Oct	0600	270.0	14.0	39.47	73.1	1.64
02 Oct	0600	270.0	25.0	70.47	130.5	2.94
03 Oct	0600	270.0	39.0	109.94	203.6	4.58
04 Oct	0600	270.0	47.0	132.49	245.4	5.52
05 Oct	0600	270.0	63.0	177.60	328.9	7.40
06 Oct	0600	270.0	57.0	160.68	297.6	6.70
07 Oct	0600	270.0	40.0	112.76	208.8	4.70
07 Oct	1700	270.0	23.0	64.84	120.1	5.89
08 Oct	0600	247.5	5.0	14.10	26.1	1.08
09 Oct	0600	247.5	11.8	33.26	61.6	1.39
09 Oct	1200	225.0	5.0	14.10	26.1	2.35
10 Oct	0600	281.2	15.5	43.69	80.9	2.43
11 Oct	0600	247.5	59.0	166.32	308.0	6.93
11 Oct	1800	247.5	27.0	76.11	141.0	6.34
12 Oct	0200	270.0	22.5	63.43	117.5	7.93

Notes: The converion factor 2.819 nautical miles per league was used throughout.

Table 01b:

Plotted course of Columbus as taken from Diary (See Marden 1986)
Starting position: 28.000N 17.000W
Starting time: 08 Sep 0300h

Watch ending Date	Time	Compass Bearing	Leagues Sailed	Nautical miles	kilo-meters	Speed knots
09 Sep	0600	270.0	9.0	25.37	47.0	0.94
10 Sep	0600	270.0	45.0	126.86	234.9	5.29
11 Sep	0600	270.0	60.0	169.14	313.2	7.05
12 Sep	0600	270.0	40.0	112.76	208.8	4.70
13 Sep	0600	270.0	33.0	93.03	172.3	3.88
14 Sep	0600	270.0	33.0	93.03	172.3	3.88
15 Sep	0600	270.0	20.0	56.38	104.4	2.35
16 Sep	0600	270.0	27.0	76.11	141.0	3.17
17 Sep	0600	270.0	39.0	109.94	203.6	4.58
18 Sep	0600	270.0	50.0	140.95	261.0	5.87
19 Sep	0600	270.0	55.0	155.04	287.1	6.46
20 Sep	0600	270.0	25.0	70.47	130.5	2.94
21 Sep	0600	286.9	7.5	21.14	39.2	0.88
22 Sep	0600	270.0	13.0	36.65	67.9	1.53
23 Sep	0600	292.5	30.0	84.57	156.6	3.52
24 Sep	0600	315.0	27.0	76.11	141.0	3.17
25 Sep	0600	270.0	14.5	40.88	75.7	1.70
26 Sep	0600	270.0	4.5	12.69	23.5	0.53
26 Sep	1800	225.0	17.0	47.92	88.8	3.99
27 Sep	0600	270.0	15.5	43.69	80.9	3.64
27 Sep	1800	225.0	15.5	43.69	80.9	3.64
28 Sep	0600	270.0	24.0	67.66	125.3	5.64
29 Sep	0600	270.0	14.0	39.47	73.1	1.64
30 Sep	0600	270.0	24.0	67.66	125.3	2.82
01 Oct	0600	270.0	14.0	39.47	73.1	1.64
02 Oct	0600	270.0	25.0	70.47	130.5	2.94
03 Oct	0600	270.0	39.0	109.94	203.6	4.58
04 Oct	0600	270.0	47.0	132.49	245.4	5.52
05 Oct	0600	270.0	63.0	177.60	328.9	7.40
06 Oct	0600	270.0	57.0	160.68	297.6	6.70
07 Oct	0600	270.0	40.0	112.76	208.8	4.70
08 Oct	0600	270.0	28.0	78.93	146.2	3.29
09 Oct	0600	247.5	11.8	33.26	61.6	1.39
09 Oct	1200	225.0	5.0	14.10	26.1	2.35
10 Oct	0600	281.2	15.5	43.69	80.9	2.43
11 Oct	0600	247.5	59.0	166.32	308.0	6.93
11 Oct	1800	247.5	27.0	76.11	141.0	6.34
12 Oct	0200	270.0	22.5	63.43	117.5	7.93

Notes: The conversion factor 2.819 nautical miles per league was use throughout.

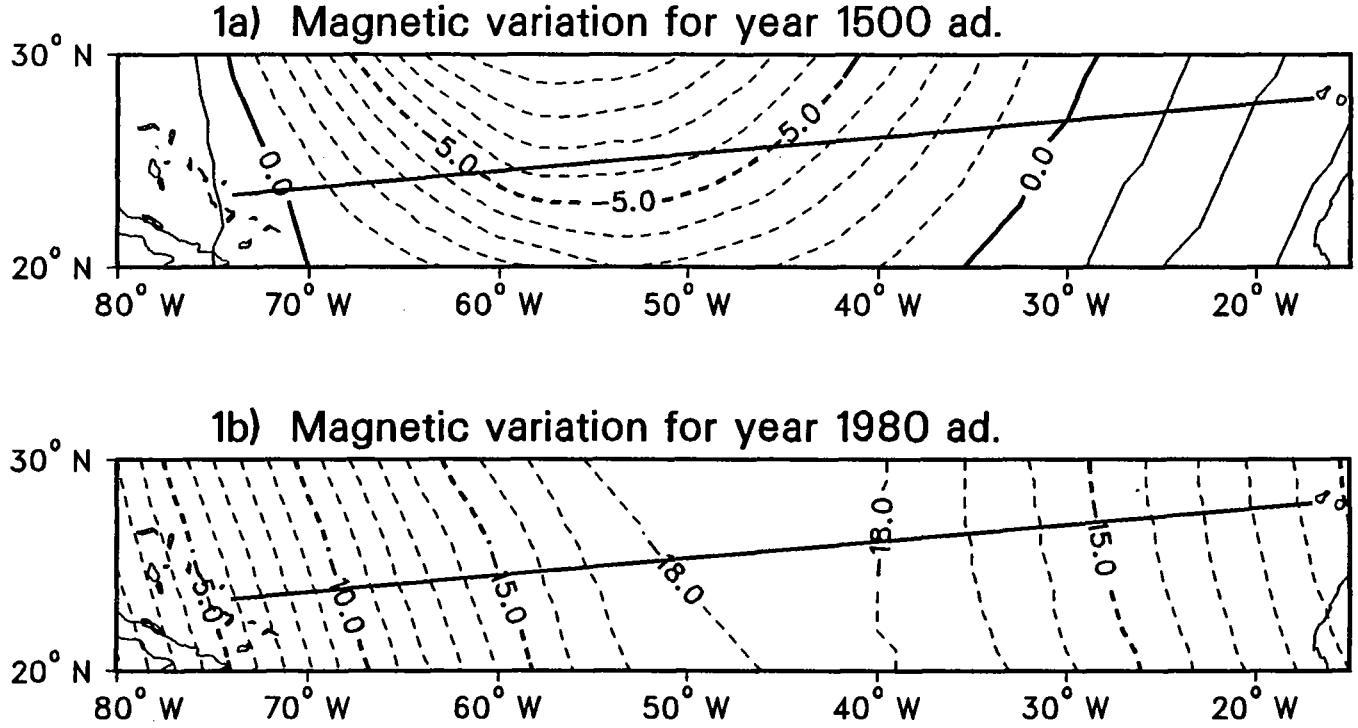
Table 02: Summary of Track Parameters and Termination Positions for all Cases

Fig.	Case	Termination Lat	Termination Lon	Position method	Compute interval	Corrections: day len	Corrections: magnetic variation	Corrections: current	Corrections: wind	Corrections: leeway factor	Comments
05	1a	26.333	-73.641	rhumb	30 min.	no					
05	1b	23.618	-72.968	rhumb	30 min.	no	vB				
05	1c	23.714	-74.299	rhumb	30 min.	no	vB	autumnal			
05	1d	23.766	-74.359	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	
05	1e	26.326	-73.900	rhumb	30 min.	yes					
05	1f	23.768	-74.620	rhumb	30 min.	yes	vB	autumnal	autumnal	0.014	
05	1g	23.655	-74.402	rhumb	30 min.	no	vB	monthly			
05	1h	23.630	-74.442	rhumb	30 min.	no	vB	monthly	monthly	0.014	
06	2a	23.766	-74.359	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	1d
06	2b	23.688	-74.337	rhumb	30 min.	no	vB	autumnal	monthly	0.014	
06	2c	23.630	-74.442	rhumb	30 min.	no	vB	monthly	monthly	0.014	1h
06	2d	23.708	-74.465	rhumb	30 min.	no	vB	monthly	autumnal	0.014	
06	2e	23.884	-74.288	rhumb	30 min.	no	vB	Sept.	Sept.	0.014	
06	2f	23.652	-74.433	rhumb	30 min.	no	vB	October	October	0.014	
07	3a	23.766	-74.359	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	1d
07	3b	23.618	-72.968	rhumb	30 min.	no	vB				1b
07	3c	23.714	-74.299	rhumb	30 min.	no	vB	autumnal			1c
07	3d	23.660	-73.007	rhumb	30 min.	no	vB		autumnal	0.014	
08	4a	23.714	-74.299	rhumb	30 min.	no	vB	autumnal	autumnal	0.0%	1c
08	4b	23.733	-74.320	rhumb	30 min.	no	vB	autumnal	autumnal	0.5%	
08	4c	23.752	-74.342	rhumb	30 min.	no	vB	autumnal	autumnal	1.0%	
08	4d	23.766	-74.359	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	1d
08	4e	23.770	-74.363	rhumb	30 min.	no	vB	autumnal	autumnal	0.015	
08	4f	23.786	-74.385	rhumb	30 min.	no	vB	autumnal	autumnal	0.020	
09	5a	23.766	-74.359	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	1d
09	5b	23.582	-74.261	rhumb	30 min.	no	vB	autumnal	autumnal	0.014	Note 1
09	5c	23.511	-74.225	rhumb	log time	no	vB	autumnal	autumnal	0.014	Note 1
09	5d	23.195	-74.185	sphere	log time	no	vB	autumnal	autumnal	0.014	Note 1
	5e	23.949	-74.435	rhumb	log time	no	vB	autumnal	autumnal	0.014	Note 2
	6a	24.014	-74.427	rhumb	30 min.	no	1492	autumnal	autumnal	0.014	Note 3
11	6b	13.518	-68.751	rhumb	30 min.	no	DMA				
		23.150	-73.487								Marden
		23.790	-74.483								McElroy

Note 1: Leeway set to 0.0 west of 40W to match Marden (1986).
Note 2: Course taken from Casebook, Table 01b (Marden, 1986b) linear interpolation.
Note 3: Magnetic variation recontructed from Columbus's log by a spatial field of minimum curvature.

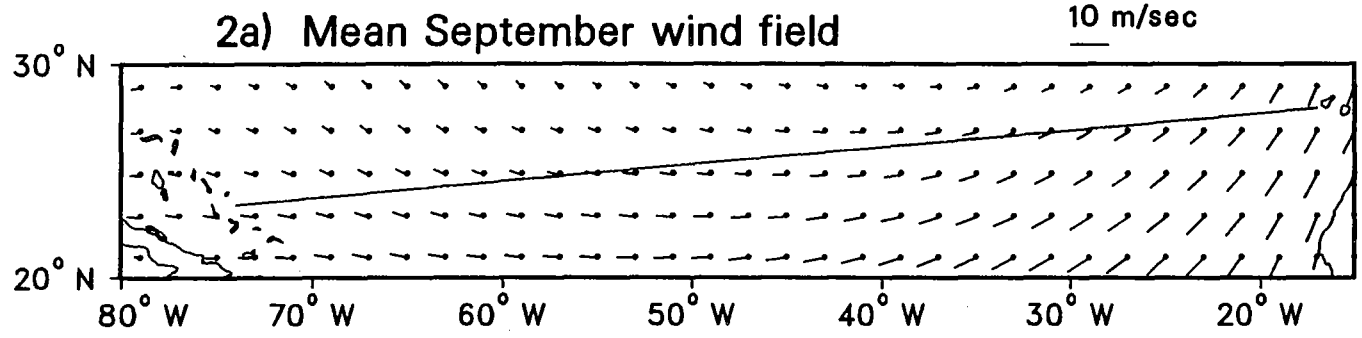
rhumb	rhumbline positioning.
sphere	spherical trigonometry positioning.
30 min.	computation cycle of 30 minutes used.
log time	computation cycle for time between log entries used.
vB	van Bemmelen magnetic variation used.
Schott	magnetic variation applied daily (Schott, 1881).
DMA	1980 magnetic variation used.
1492	magnetic variation recontructed from Columbus's log
monthly	appropriate September or October velocity field used, based on corrected Gregorian date.
autumnal	average September + October velocity field used.
September	September velocity field used for entire voyage.
October	October velocity field used for entire voyage.

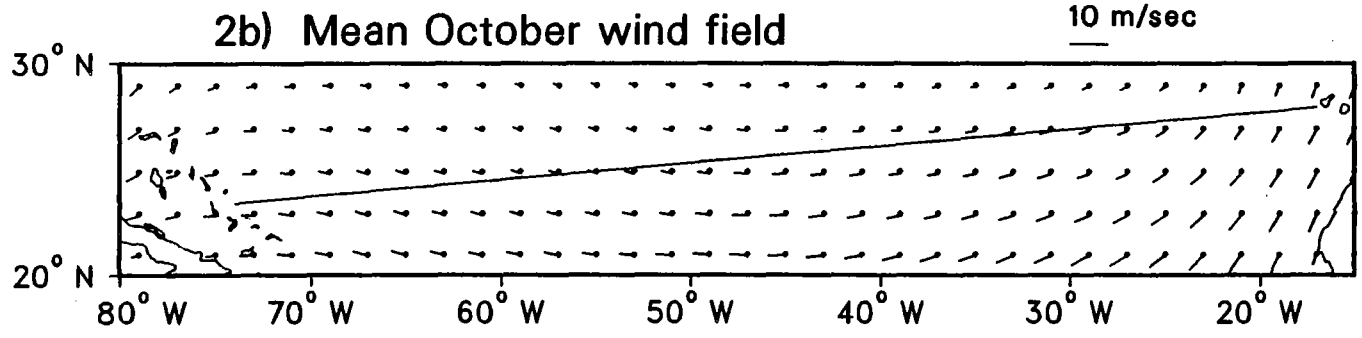
Figures



Track made good between voyage start and end positions is shown.
Dashed lines indicate westward deflections and are applied as negative corrections to the compass bearing to obtain true bearing. (Mercator projection).

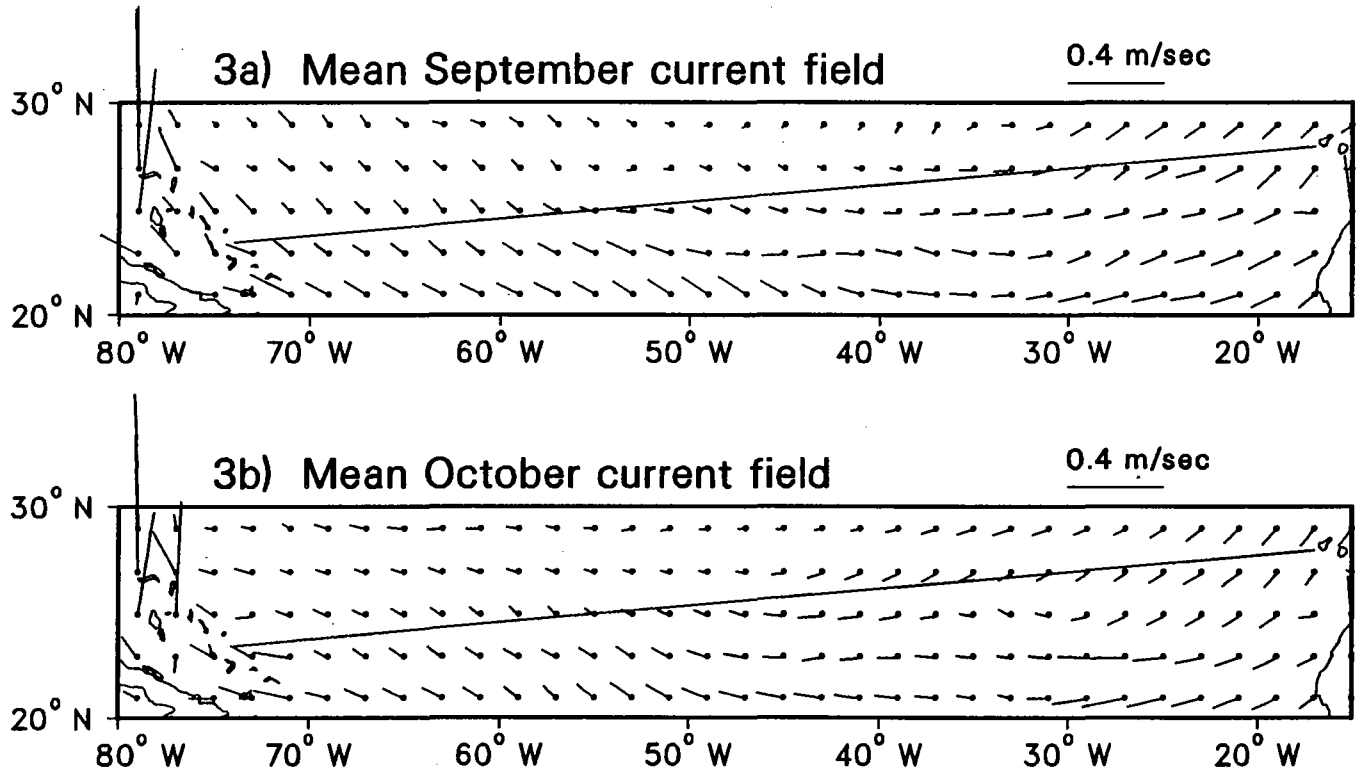
Figure 1a: Magnetic variation, in degrees from true north, for the year 1500, from van Bemmelen (1899) as mapped by McElroy (1941).
Figure 1b: Modern (1980) isogonic lines, from Defense Mapping Agency chart WOAGN12.





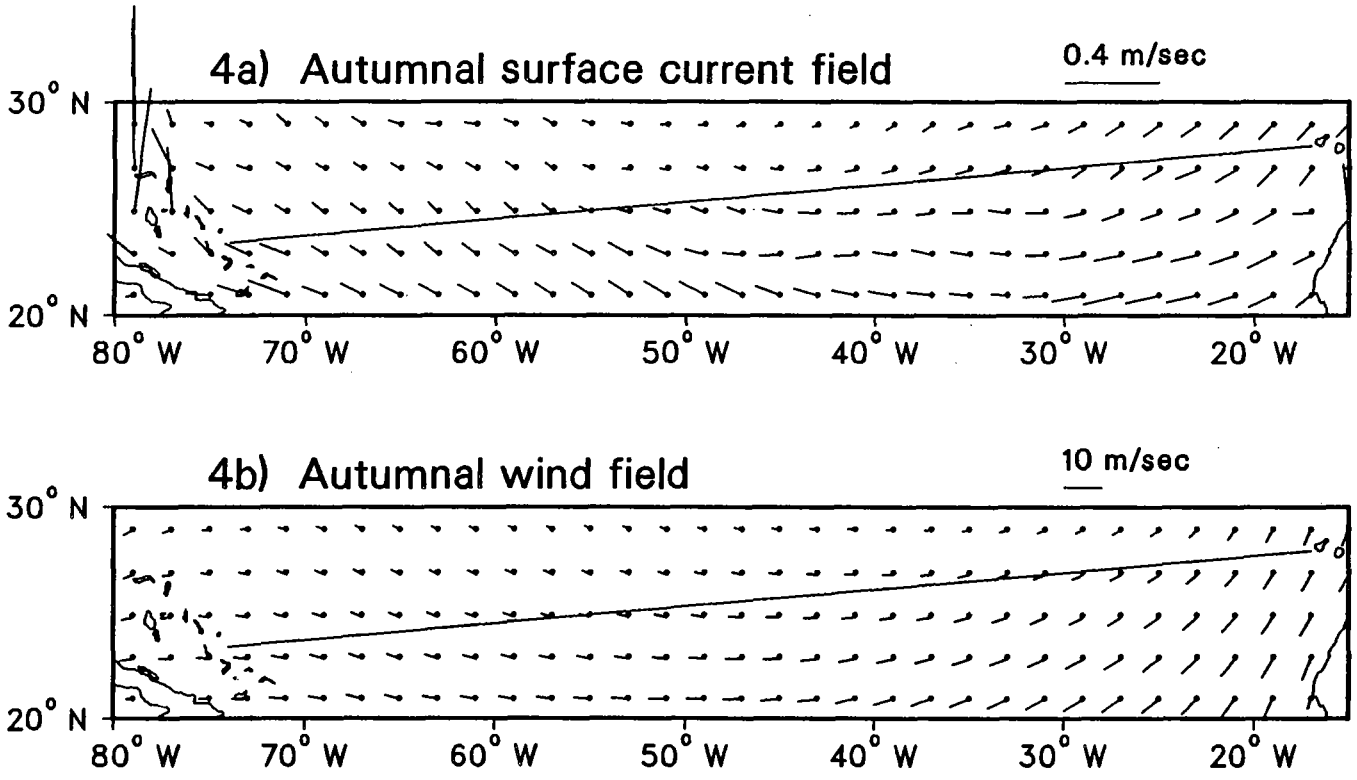
Monthly mean wind fields shown at 2 degree subsample. (Mercator projection).

Figure 2a: Mean wind field for September, from Isemer/Hasse (1985).
Figure 2b: Mean wind field for October.



Mean monthly current fields shown at 2 degree subsample.
Taken from historical shipdrift analysis (Mercator projection).

Figure 3a: Mean current field for September.
Figure 3b: Mean current field for October.



Mean autumnal (September+October) fields shown at 2 degree subsample. (Merçator projection)

Figure 4a: Mean autumnal current field, from historical shipdrift analysis.
Figure 4b: Mean autumnal wind field, from Isemer/Hasse (1985).

Figure 5: Scenario Endpoints for Columbus Voyage

Chart shows the endpoints of the track as successive corrections are applied. The dashed lines represent the track for the final day of the voyage. (Mercator projection).

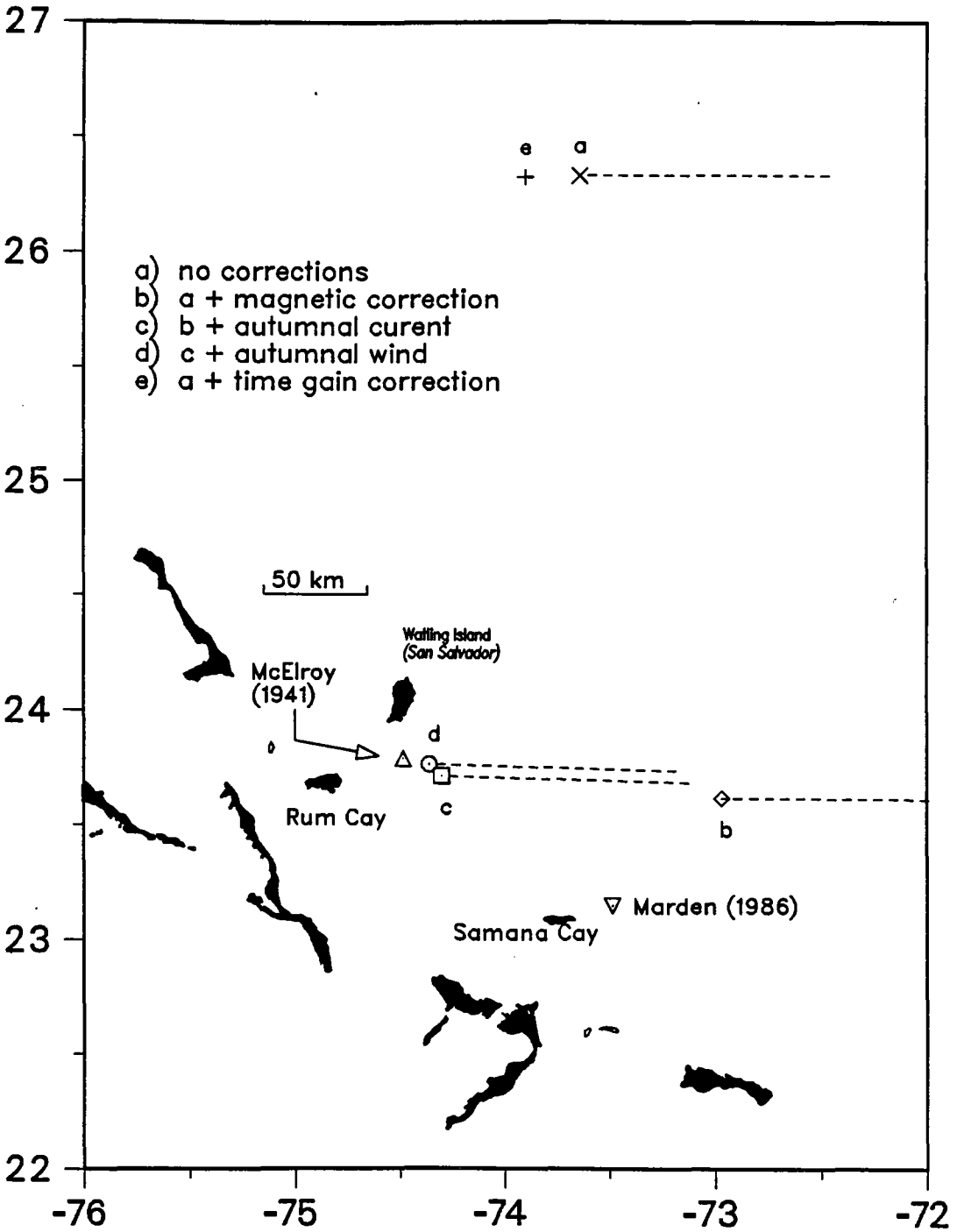
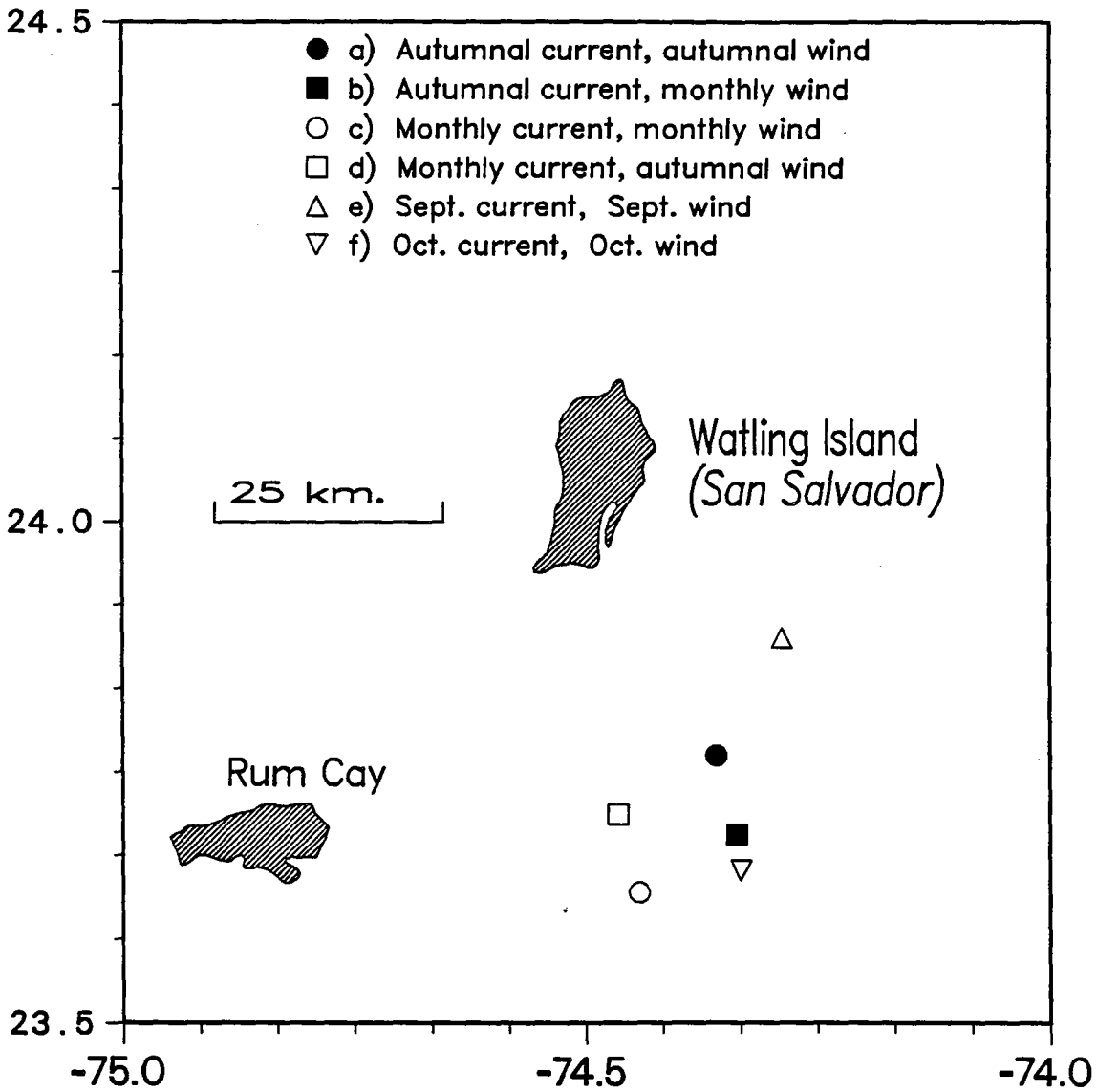


Figure 6: Effect of Various Current and Wind Fields on Columbus Track Termination



Track endpoints as determined by various current and wind fields. 'Autumnal' means average over September and October — 'monthly' means the September field was used for the corrected Gregorian date September portion of the voyage, October fields for October dates. All cases used a leeway factor of 0.014. (Mercator projection)

Figure 7: Effect of Wind and Current Fields on Columbus Track Termination

Track endpoints showing relative influence of mean autumnal(September and October) wind and current fields. Magnetic corrections and leeway factor = 0.014 were applied in all cases. (Mercator projection).

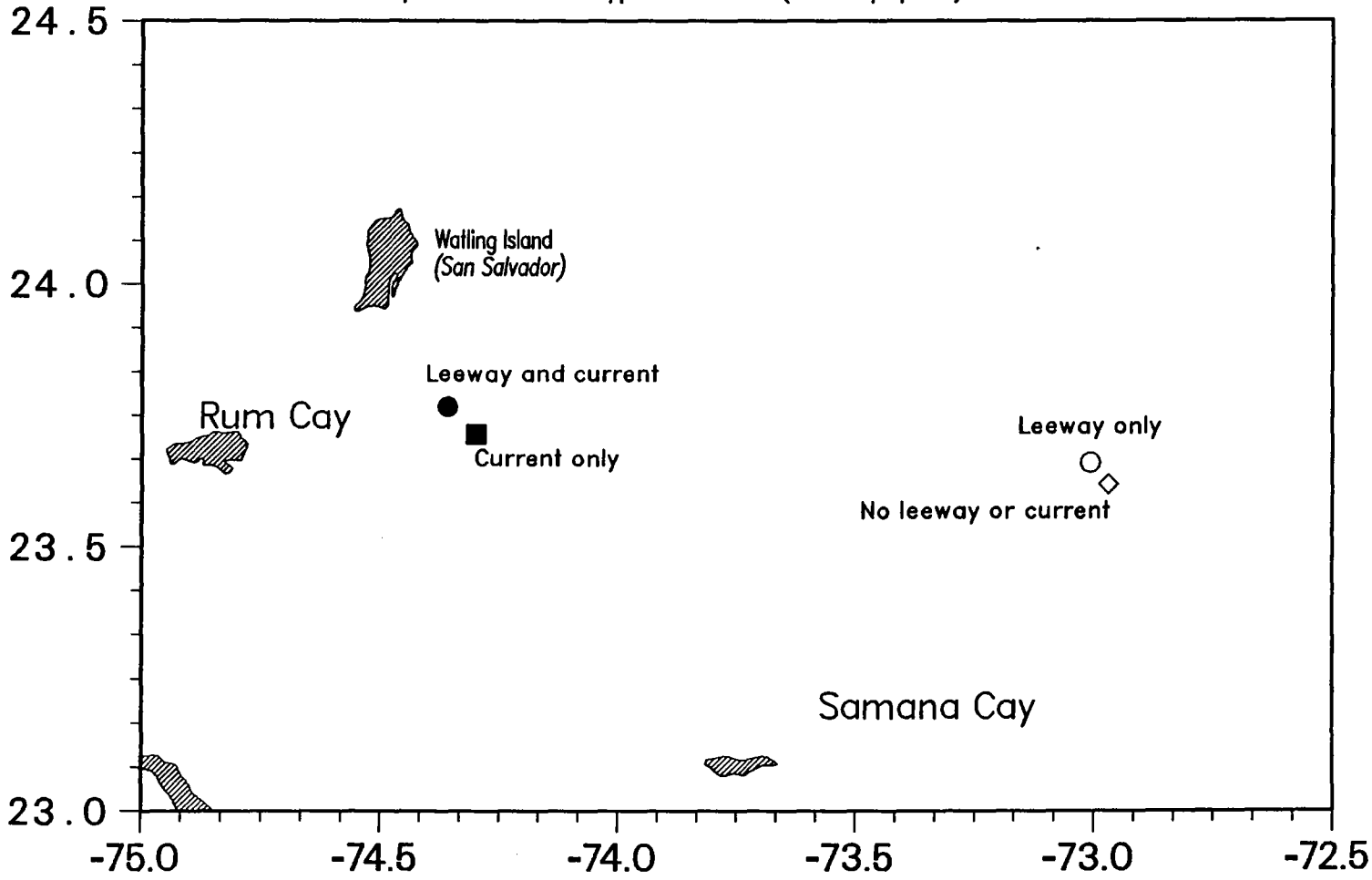


Figure 8: Effect of Varying Leeway Factor on Columbus Track Termination

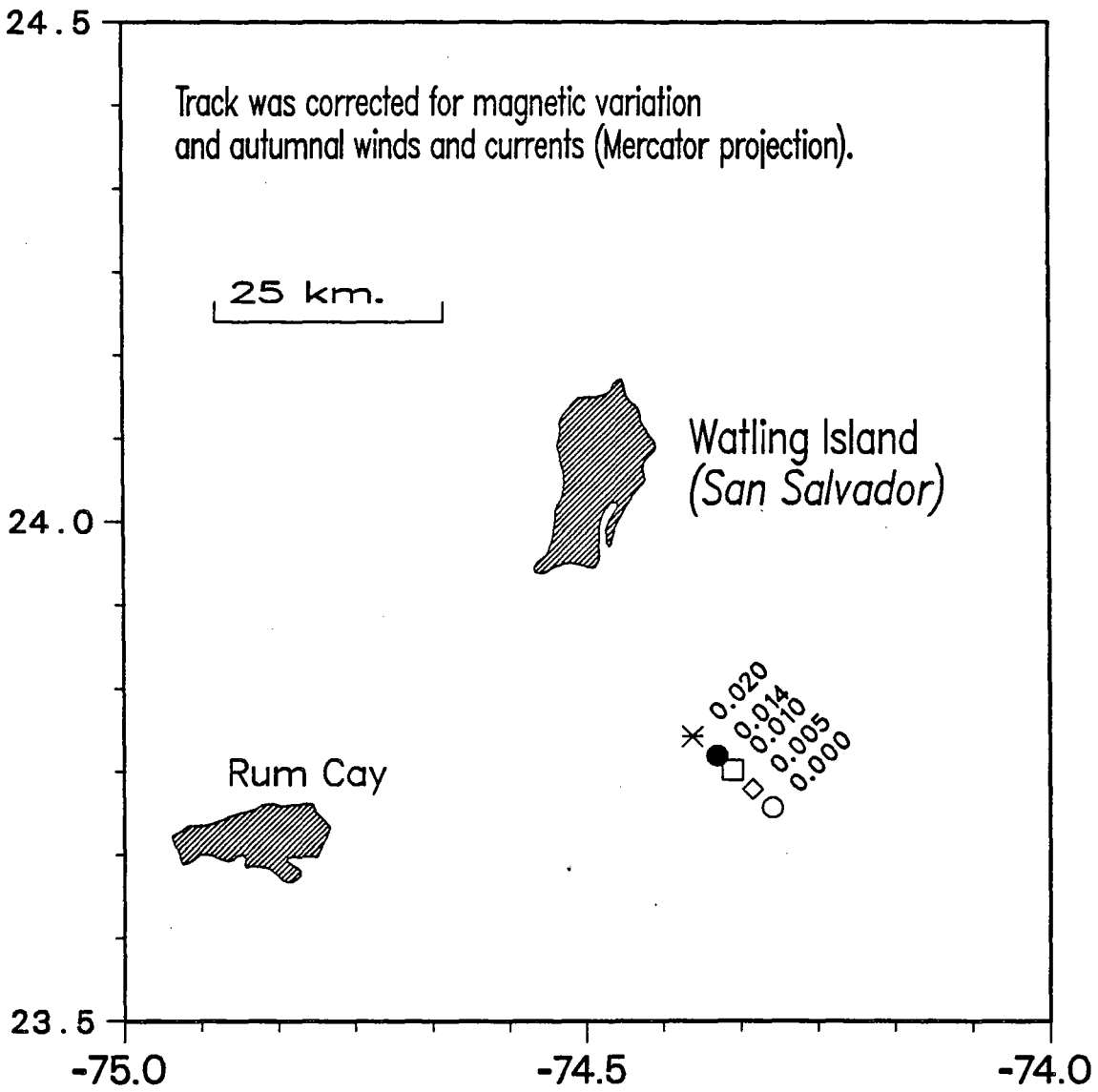
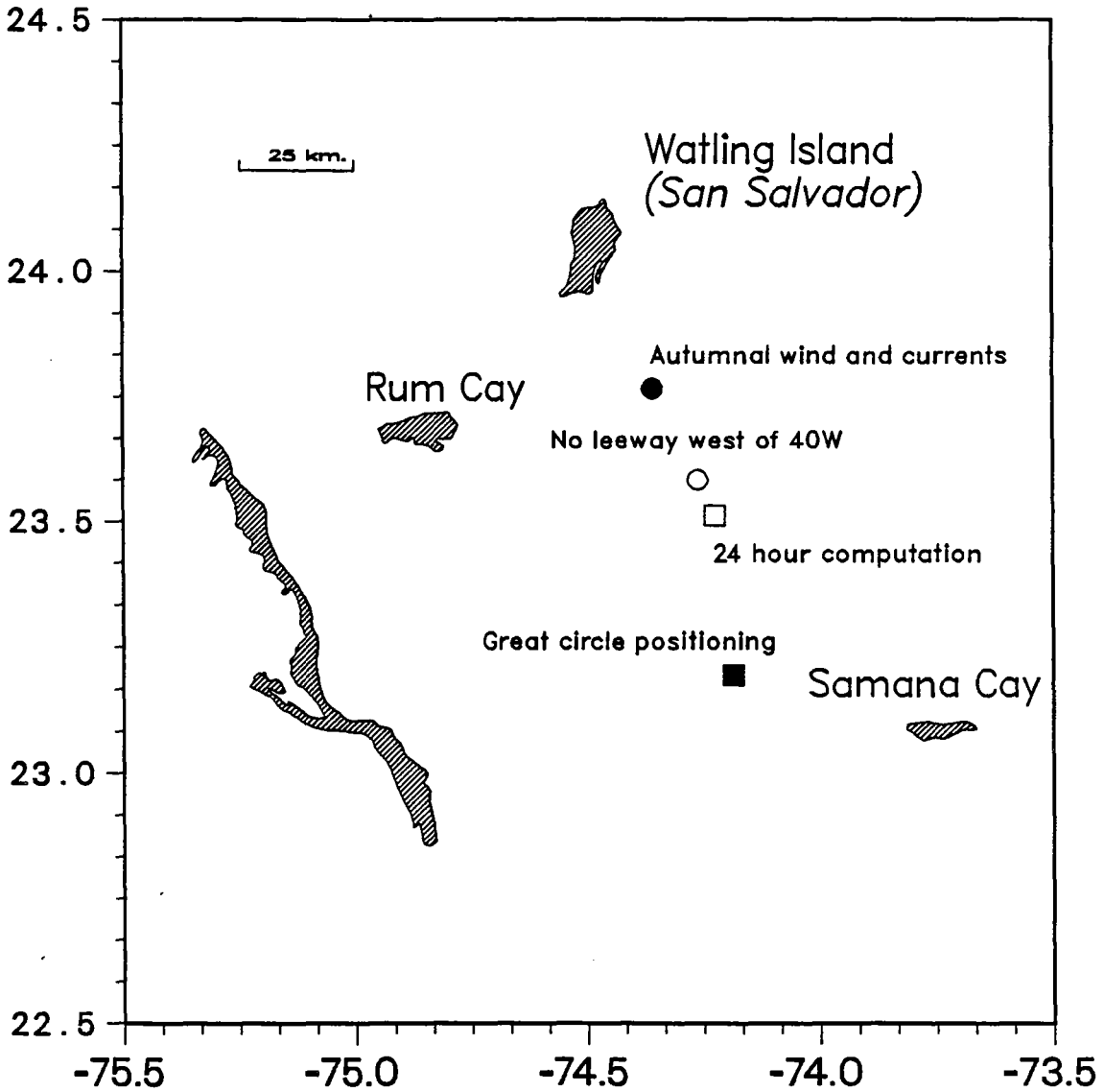
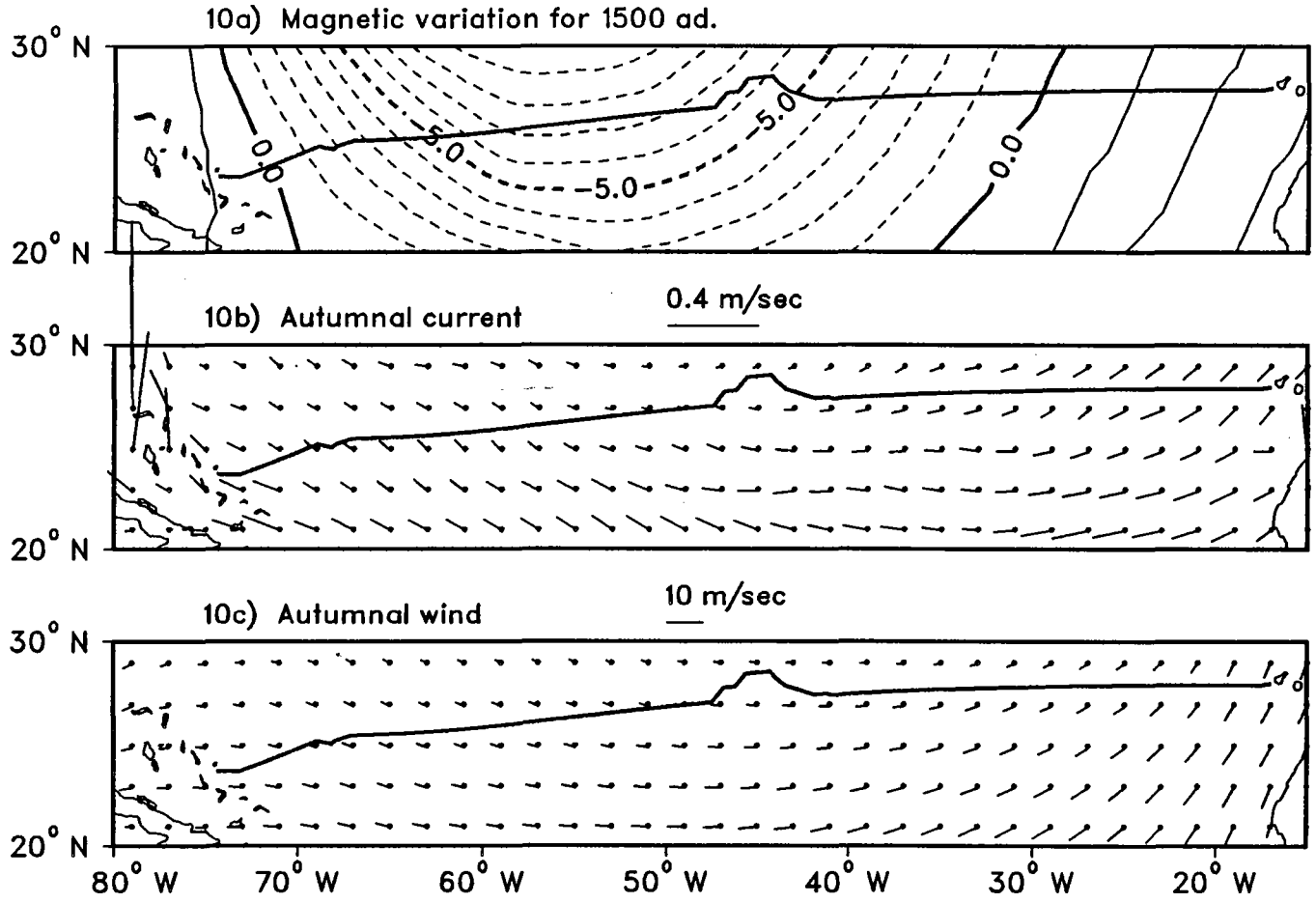


Figure 9: Limited Leeway and Positioning Effects on Columbus Track Termination

Cumulative effects on track endpoints by removing leeway west of 40W, using 24 hour computation interval, and great circle positioning. All cases use magnetic correction and leeway factor of 0.014. (Mercator projection).





Figures 10: Best corrected track shown through environment fields. Vector fields are shown subsampled every two degrees. Magnetic field taken from van Bemmelen (1899); dashed lines are westward deflections, in degrees. (Mercator projection).

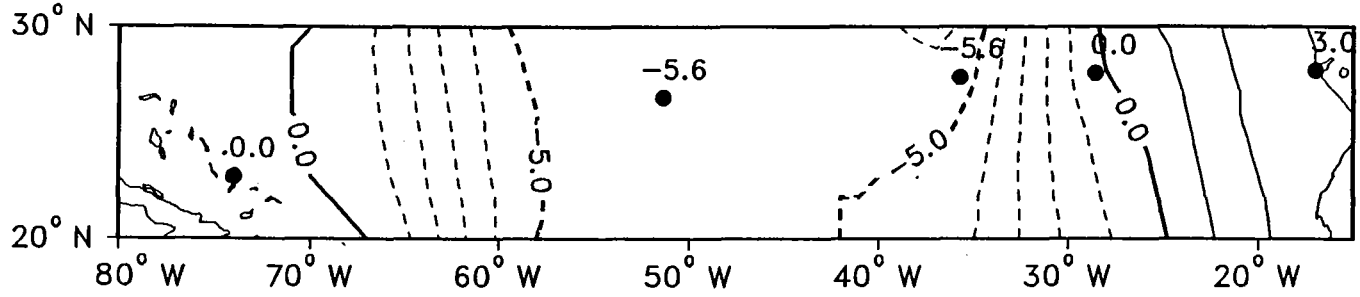


Figure 11a: Magnetic variation (degrees from true north) for the year 1492, constructed from the three observations recorded by Columbus along his track. The value 3.0 for the Canary Islands is from Van Bemmelen (1899); the value for the Bahamas (0.0) is from Schott (1881).

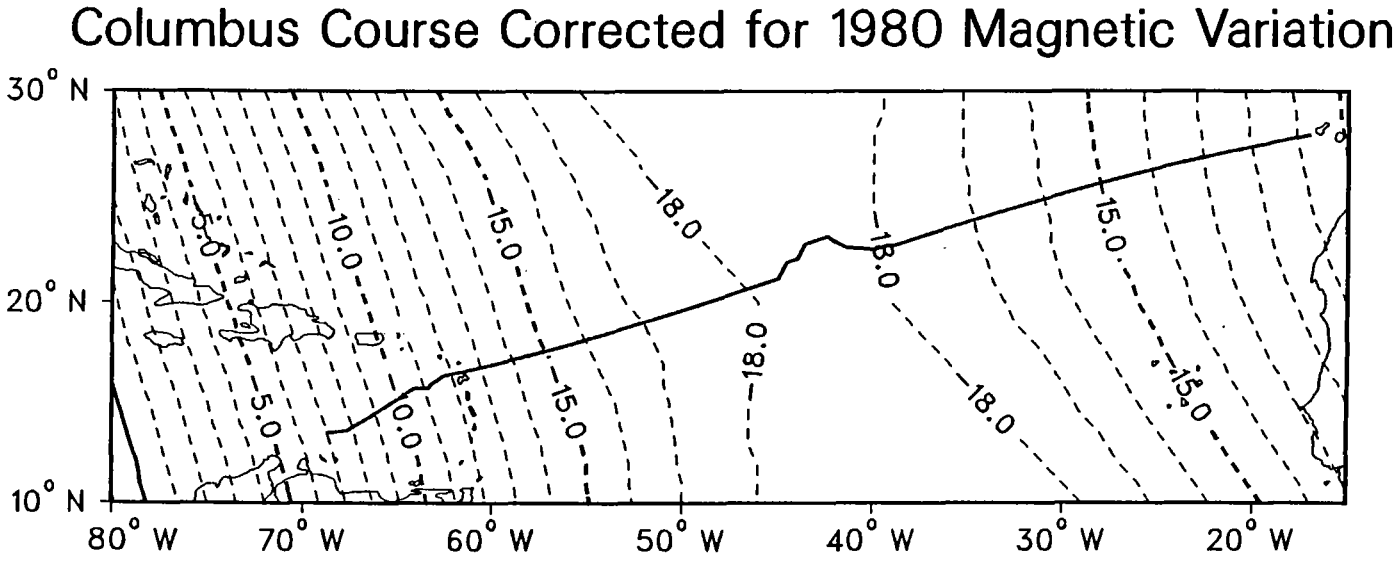


Figure 11b:
Hypothetical track superimposed on the 1980 magnetic variation field. No current or wind fields were used. Magnetic field was taken from Defense Mapping Agency chart WOAGN12 (1982). Dashed lines are westward deflections (negative corrections).

Appendix

CASE SCENARIO SUMMARIES

Case 01a Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: not used
Current field: not used
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Postition	
Mon Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep 09	0600	270.0	0.0	270.0	9.00	46.99	0.000	0.0	0.000	0.0	0.00	28.005	-17.470
Sep 10	0600	270.0	0.0	270.0	45.00	234.94	0.000	0.0	0.000	0.0	0.00	28.005	-19.860
Sep 11	0600	270.0	0.0	270.0	60.00	313.25	0.000	0.0	0.000	0.0	0.00	28.005	-23.047
Sep 12	0600	270.0	0.0	270.0	40.00	208.83	0.000	0.0	0.000	0.0	0.00	28.005	-25.172
Sep 13	0600	270.0	0.0	270.0	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.005	-26.925
Sep 14	0600	270.0	0.0	270.0	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.005	-28.678
Sep 15	0600	270.0	0.0	270.0	20.00	104.42	0.000	0.0	0.000	0.0	0.00	28.005	-29.740
Sep 16	0600	270.0	0.0	270.0	27.00	140.96	0.000	0.0	0.000	0.0	0.00	28.005	-31.174
Sep 17	0600	270.0	0.0	270.0	39.00	203.61	0.000	0.0	0.000	0.0	0.00	28.005	-33.246
Sep 18	0600	270.0	0.0	270.0	50.00	261.04	0.000	0.0	0.000	0.0	0.00	28.005	-35.902
Sep 19	0600	270.0	0.0	270.0	55.00	287.14	0.000	0.0	0.000	0.0	0.00	28.005	-38.823
Sep 20	0600	270.0	0.0	270.0	25.00	130.52	0.000	0.0	0.000	0.0	0.00	28.005	-40.151
Sep 20	1800	281.2	0.0	281.2	3.80	19.84	0.000	0.0	0.000	0.0	0.00	28.040	-40.349
Sep 21	0600	292.5	0.0	292.5	3.80	19.84	0.000	0.0	0.000	0.0	0.00	28.108	-40.535
Sep 22	0600	270.0	0.0	270.0	13.00	67.87	0.000	0.0	0.000	0.0	0.00	28.108	-41.227
Sep 23	0600	292.5	0.0	292.5	30.00	156.62	0.000	0.0	0.000	0.0	0.00	28.646	-42.704
Sep 23	1800	315.0	0.0	315.0	13.50	70.48	0.000	0.0	0.000	0.0	0.00	29.094	-43.215
Sep 24	0100	326.2	0.0	326.2	8.10	42.29	0.000	0.0	0.000	0.0	0.00	29.410	-43.457
Sep 24	0600	270.0	0.0	270.0	5.40	28.19	0.000	0.0	0.000	0.0	0.00	29.410	-43.748
Sep 25	0600	270.0	0.0	270.0	14.50	75.70	0.000	0.0	0.000	0.0	0.00	29.410	-44.529
Sep 25	1800	270.0	0.0	270.0	4.50	23.49	0.000	0.0	0.000	0.0	0.00	29.410	-44.771
Sep 26	0600	225.0	0.0	225.0	17.00	88.75	0.000	0.0	0.000	0.0	0.00	28.846	-45.416
Sep 26	1500	270.0	0.0	270.0	11.60	60.56	0.000	0.0	0.000	0.0	0.00	28.846	-46.037
Sep 27	0600	225.0	0.0	225.0	19.40	101.28	0.000	0.0	0.000	0.0	0.00	28.203	-46.770
Sep 28	0600	270.0	0.0	270.0	24.00	125.30	0.000	0.0	0.000	0.0	0.00	28.203	-48.047
Sep 29	0600	270.0	0.0	270.0	14.00	73.09	0.000	0.0	0.000	0.0	0.00	28.203	-48.792
Sep 30	0600	270.0	0.0	270.0	24.00	125.30	0.000	0.0	0.000	0.0	0.00	28.203	-50.069
Oct 01	0600	270.0	0.0	270.0	14.00	73.09	0.000	0.0	0.000	0.0	0.00	28.203	-50.814
Oct 02	0600	270.0	0.0	270.0	25.00	130.52	0.000	0.0	0.000	0.0	0.00	28.203	-52.145
Oct 03	0600	270.0	0.0	270.0	39.00	203.61	0.000	0.0	0.000	0.0	0.00	28.203	-54.220
Oct 04	0600	270.0	0.0	270.0	47.00	245.38	0.000	0.0	0.000	0.0	0.00	28.203	-56.721
Oct 05	0600	270.0	0.0	270.0	63.00	328.91	0.000	0.0	0.000	0.0	0.00	28.203	-60.073
Oct 06	0600	270.0	0.0	270.0	57.00	297.58	0.000	0.0	0.000	0.0	0.00	28.203	-63.107
Oct 07	0600	270.0	0.0	270.0	40.00	208.83	0.000	0.0	0.000	0.0	0.00	28.203	-65.235
Oct 07	1700	270.0	0.0	270.0	23.00	120.08	0.000	0.0	0.000	0.0	0.00	28.203	-66.459
Oct 08	0600	247.5	0.0	247.5	5.00	26.10	0.000	0.0	0.000	0.0	0.00	28.113	-66.705
Oct 09	0600	247.5	0.0	247.5	11.80	61.61	0.000	0.0	0.000	0.0	0.00	27.901	-67.284
Oct 09	1200	225.0	0.0	225.0	5.00	26.10	0.000	0.0	0.000	0.0	0.00	27.735	-67.471
Oct 10	0600	281.2	0.0	281.2	15.50	80.92	0.000	0.0	0.000	0.0	0.00	27.876	-68.278
Oct 11	0600	247.5	0.0	247.5	59.00	308.03	0.000	0.0	0.000	0.0	0.00	26.818	-71.156
Oct 11	1800	247.5	0.0	247.5	27.00	140.96	0.000	0.0	0.000	0.0	0.00	26.333	-72.464
Oct 12	0200	270.0	0.0	270.0	22.50	117.47	0.000	0.0	0.000	0.0	0.00	26.333	-73.641

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01b: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: not used
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon	Da Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09 0600	270.0	2.4	272.4	9.00	46.99	0.000	0.0	0.000	0.0	0.00	28.023	-17.470
Sep	10 0600	270.0	2.0	272.0	45.00	234.94	0.000	0.0	0.000	0.0	0.00	28.103	-19.860
Sep	11 0600	270.0	1.3	271.3	60.00	313.25	0.000	0.0	0.000	0.0	0.00	28.184	-23.049
Sep	12 0600	270.0	0.9	270.9	40.00	208.83	0.000	0.0	0.000	0.0	0.00	28.219	-25.178
Sep	13 0600	270.0	0.5	270.5	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.237	-26.934
Sep	14 0600	270.0	0.1	270.1	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.246	-28.691
Sep	15 0600	270.0	-0.1	269.9	20.00	104.42	0.000	0.0	0.000	0.0	0.00	28.246	-29.755
Sep	16 0600	270.0	-0.4	269.6	27.00	140.96	0.000	0.0	0.000	0.0	0.00	28.241	-31.193
Sep	17 0600	270.0	-1.1	268.9	39.00	203.61	0.000	0.0	0.000	0.0	0.00	28.217	-33.269
Sep	18 0600	270.0	-2.1	267.9	50.00	261.04	0.000	0.0	0.000	0.0	0.00	28.152	-35.928
Sep	19 0600	270.0	-3.3	266.7	55.00	287.14	0.000	0.0	0.000	0.0	0.00	28.030	-38.848
Sep	20 0600	270.0	-3.8	266.2	25.00	130.52	0.000	0.0	0.000	0.0	0.00	27.956	-40.174
Sep	20 1800	281.2	-3.9	277.3	3.80	19.84	0.000	0.0	0.000	0.0	0.00	27.979	-40.374
Sep	21 0600	292.5	-4.0	288.5	3.80	19.84	0.000	0.0	0.000	0.0	0.00	28.036	-40.565
Sep	22 0600	270.0	-4.3	265.7	13.00	67.87	0.000	0.0	0.000	0.0	0.00	27.991	-41.254
Sep	23 0600	292.5	-5.2	287.3	30.00	156.62	0.000	0.0	0.000	0.0	0.00	28.420	-42.775
Sep	23 1800	315.0	-5.5	309.5	13.50	70.48	0.000	0.0	0.000	0.0	0.00	28.824	-43.330
Sep	24 0100	326.2	-5.8	320.4	8.10	42.29	0.000	0.0	0.000	0.0	0.00	29.117	-43.606
Sep	24 0600	270.0	-5.9	264.1	5.40	28.19	0.000	0.0	0.000	0.0	0.00	29.091	-43.894
Sep	25 0600	270.0	-6.2	263.8	14.50	75.70	0.000	0.0	0.000	0.0	0.00	29.020	-44.668
Sep	25 1800	270.0	-6.3	263.7	4.50	23.49	0.000	0.0	0.000	0.0	0.00	28.996	-44.908
Sep	26 0600	225.0	-6.3	218.7	17.00	88.75	0.000	0.0	0.000	0.0	0.00	28.374	-45.476
Sep	26 1500	270.0	-6.5	263.5	11.60	60.56	0.000	0.0	0.000	0.0	0.00	28.314	-46.090
Sep	27 0600	225.0	-6.4	218.6	19.40	101.28	0.000	0.0	0.000	0.0	0.00	27.602	-46.732
Sep	28 0600	270.0	-6.7	263.3	24.00	125.30	0.000	0.0	0.000	0.0	0.00	27.473	-47.993
Sep	29 0600	270.0	-6.9	263.1	14.00	73.09	0.000	0.0	0.000	0.0	0.00	27.395	-48.727
Sep	30 0600	270.0	-7.2	262.8	24.00	125.30	0.000	0.0	0.000	0.0	0.00	27.256	-49.985
Oct	01 0600	270.0	-7.4	262.6	14.00	73.09	0.000	0.0	0.000	0.0	0.00	27.172	-50.717
Oct	02 0600	270.0	-7.5	262.5	25.00	130.52	0.000	0.0	0.000	0.0	0.00	27.019	-52.023
Oct	03 0600	270.0	-7.6	262.4	39.00	203.61	0.000	0.0	0.000	0.0	0.00	26.779	-54.056
Oct	04 0600	270.0	-7.5	262.5	47.00	245.38	0.000	0.0	0.000	0.0	0.00	26.489	-56.500
Oct	05 0600	270.0	-6.9	263.1	63.00	328.91	0.000	0.0	0.000	0.0	0.00	26.113	-59.769
Oct	06 0600	270.0	-5.2	264.8	57.00	297.58	0.000	0.0	0.000	0.0	0.00	25.831	-62.726
Oct	07 0600	270.0	-4.0	266.0	40.00	208.83	0.000	0.0	0.000	0.0	0.00	25.681	-64.802
Oct	07 1700	270.0	-3.3	266.7	23.00	120.08	0.000	0.0	0.000	0.0	0.00	25.612	-65.996
Oct	08 0600	247.5	-3.1	244.4	5.00	26.10	0.000	0.0	0.000	0.0	0.00	25.511	-66.230
Oct	09 0600	247.5	-2.7	244.8	11.80	61.61	0.000	0.0	0.000	0.0	0.00	25.273	-66.783
Oct	09 1200	225.0	-2.5	222.5	5.00	26.10	0.000	0.0	0.000	0.0	0.00	25.100	-66.958
Oct	10 0600	281.2	-2.1	279.1	15.50	80.92	0.000	0.0	0.000	0.0	0.00	25.213	-67.752
Oct	11 0600	247.5	-0.4	247.1	59.00	308.03	0.000	0.0	0.000	0.0	0.00	24.099	-70.538
Oct	11 1800	247.5	0.2	247.7	27.00	140.96	0.000	0.0	0.000	0.0	0.00	23.612	-71.816
Oct	12 0200	270.0	0.5	270.5	22.50	117.47	0.000	0.0	0.000	0.0	0.00	23.618	-72.968

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01c: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.084	222.0	0.000	0.0	0.00	27.970	-17.523
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.089	231.4	0.000	0.0	0.00	28.003	-19.967
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.089	242.4	0.000	0.0	0.00	28.047	-23.220
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.076	239.2	0.000	0.0	0.00	28.049	-25.409
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.067	236.4	0.000	0.0	0.00	28.037	-27.215
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.063	242.0	0.000	0.0	0.00	28.019	-29.016
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.062	247.3	0.000	0.0	0.00	27.998	-30.128
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.063	254.3	0.000	0.0	0.00	27.976	-31.614
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.060	256.3	0.000	0.0	0.00	27.937	-33.737
Sep	18	0600	270.0	-2.2	267.8	50.00	261.04	0.054	250.7	0.000	0.0	0.00	27.855	-36.437
Sep	19	0600	270.0	-3.4	266.6	55.00	287.14	0.045	252.8	0.000	0.0	0.00	27.715	-39.390
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.042	256.7	0.000	0.0	0.00	27.630	-40.748
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.041	257.2	0.000	0.0	0.00	27.649	-40.965
Sep	21	0600	292.5	-4.2	288.3	3.80	19.84	0.040	257.5	0.000	0.0	0.00	27.702	-41.174
Sep	22	0600	270.0	-4.5	265.5	13.00	67.87	0.039	260.0	0.000	0.0	0.00	27.650	-41.894
Sep	23	0600	292.5	-5.3	287.2	30.00	156.62	0.032	263.7	0.000	0.0	0.00	28.072	-43.441
Sep	23	1800	315.0	-5.7	309.3	13.50	70.48	0.028	262.4	0.000	0.0	0.00	28.473	-44.009
Sep	24	0100	326.2	-5.9	320.3	8.10	42.29	0.026	259.9	0.000	0.0	0.00	28.765	-44.292
Sep	24	0600	270.0	-6.1	263.9	5.40	28.19	0.026	260.7	0.000	0.0	0.00	28.738	-44.584
Sep	25	0600	270.0	-6.4	263.6	14.50	75.70	0.026	263.9	0.000	0.0	0.00	28.661	-45.378
Sep	25	1800	270.0	-6.5	263.5	4.50	23.49	0.027	265.0	0.000	0.0	0.00	28.636	-45.628
Sep	26	0600	225.0	-6.4	218.6	17.00	88.75	0.032	275.6	0.000	0.0	0.00	28.013	-46.206
Sep	26	1500	270.0	-6.6	263.4	11.60	60.56	0.032	279.4	0.000	0.0	0.00	27.953	-46.828
Sep	27	0600	225.0	-6.5	218.5	19.40	101.28	0.038	289.2	0.000	0.0	0.00	27.245	-47.485
Sep	28	0600	270.0	-6.8	263.2	24.00	125.30	0.038	288.6	0.000	0.0	0.00	27.125	-48.773
Sep	29	0600	270.0	-7.0	263.0	14.00	73.09	0.037	286.1	0.000	0.0	0.00	27.055	-49.536
Sep	30	0600	270.0	-7.3	262.7	24.00	125.30	0.036	281.4	0.000	0.0	0.00	26.921	-50.820
Oct	01	0600	270.0	-7.4	262.6	14.00	73.09	0.036	278.6	0.000	0.0	0.00	26.842	-51.581
Oct	02	0600	270.0	-7.4	262.6	25.00	130.52	0.038	279.5	0.000	0.0	0.00	26.696	-52.915
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.044	294.7	0.000	0.0	0.00	26.469	-54.977
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.052	307.7	0.000	0.0	0.00	26.205	-57.451
Oct	05	0600	270.0	-6.3	263.7	63.00	328.91	0.059	308.5	0.000	0.0	0.00	25.875	-60.753
Oct	06	0600	270.0	-4.5	265.5	57.00	297.58	0.061	308.4	0.000	0.0	0.00	25.653	-63.748
Oct	07	0600	270.0	-3.3	266.7	40.00	208.83	0.060	306.2	0.000	0.0	0.00	25.553	-65.865
Oct	07	1700	270.0	-2.7	267.3	23.00	120.08	0.060	304.6	0.000	0.0	0.00	25.509	-67.078
Oct	08	0600	247.5	-2.5	245.0	5.00	26.10	0.062	304.7	0.000	0.0	0.00	25.425	-67.337
Oct	09	0600	247.5	-2.1	245.4	11.80	61.61	0.065	304.9	0.000	0.0	0.00	25.221	-67.937
Oct	09	1200	225.0	-1.9	223.1	5.00	26.10	0.067	305.3	0.000	0.0	0.00	25.057	-68.126
Oct	10	0600	281.2	-1.5	279.7	15.50	80.92	0.069	307.0	0.000	0.0	0.00	25.200	-68.953
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.097	303.6	0.000	0.0	0.00	24.140	-71.807
Oct	11	1800	247.5	0.5	248.0	27.00	140.96	0.103	303.4	0.000	0.0	0.00	23.686	-73.126
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.088	315.4	0.000	0.0	0.00	23.714	-74.299

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01d: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.084	221.8	4.427	209.1	3.95	27.921	-17.526
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.089	231.5	3.674	215.1	3.08	27.916	-19.969
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.090	243.1	3.024	228.5	2.05	27.933	-23.222
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.076	239.5	2.901	237.0	1.62	27.917	-25.408
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.065	235.9	2.726	242.7	1.27	27.889	-27.211
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.062	241.4	2.656	246.9	1.05	27.859	-29.009
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.061	246.8	2.695	247.7	1.02	27.827	-30.118
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.063	253.8	2.757	249.0	0.97	27.794	-31.601
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.061	256.2	2.682	253.8	0.70	27.748	-33.721
Sep	18	0600	270.0	-2.1	267.9	50.00	261.04	0.055	251.8	2.488	261.7	0.27	27.663	-36.417
Sep	19	0600	270.0	-3.3	266.7	55.00	287.14	0.047	254.3	2.435	268.6	0.08	27.525	-39.366
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.044	257.8	2.507	269.2	0.13	27.444	-40.724
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.043	258.3	2.512	269.3	0.35	27.462	-40.942
Sep	21	0600	292.5	-4.1	288.4	3.80	19.84	0.042	258.6	2.496	269.7	0.80	27.511	-41.152
Sep	22	0600	270.0	-4.4	265.6	13.00	67.87	0.041	260.9	2.514	270.4	0.21	27.462	-41.874
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.034	264.9	2.390	274.0	0.55	27.879	-43.422
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.030	264.2	2.292	276.1	1.26	28.276	-43.994
Sep	24	0100	326.2	-5.8	320.4	8.10	42.29	0.027	262.3	2.181	277.5	1.48	28.565	-44.280
Sep	24	0600	270.0	-6.0	264.0	5.40	28.19	0.027	263.2	2.182	277.8	0.52	28.540	-44.572
Sep	25	0600	270.0	-6.3	263.7	14.50	75.70	0.028	266.7	2.210	278.5	0.56	28.471	-45.367
Sep	25	1800	270.0	-6.4	263.6	4.50	23.49	0.028	267.8	2.219	278.7	0.58	28.451	-45.618
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.033	277.8	2.441	277.8	2.10	27.836	-46.206
Sep	26	1500	270.0	-6.5	263.5	11.60	60.56	0.034	281.7	2.465	278.7	0.64	27.779	-46.828
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.039	290.8	2.663	278.5	2.30	27.082	-47.499
Sep	28	0600	270.0	-6.7	263.3	24.00	125.30	0.039	289.6	2.631	280.9	0.80	26.972	-48.787
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.038	286.8	2.576	282.3	0.85	26.913	-49.552
Sep	30	0600	270.0	-7.2	262.8	24.00	125.30	0.038	282.1	2.501	284.6	0.93	26.791	-50.837
Oct	01	0600	270.0	-7.3	262.7	14.00	73.09	0.038	279.3	2.466	286.0	0.97	26.724	-51.600
Oct	02	0600	270.0	-7.3	262.7	25.00	130.52	0.039	280.2	2.429	288.3	1.05	26.590	-52.936
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.044	295.1	2.484	289.7	1.13	26.378	-54.998
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.053	307.9	2.659	289.7	1.21	26.129	-57.473
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.059	308.9	2.640	291.3	1.22	25.815	-60.775
Oct	06	0600	270.0	-4.5	265.5	57.00	297.58	0.061	308.7	2.759	292.8	1.27	25.610	-63.771
Oct	07	0600	270.0	-3.3	266.7	40.00	208.83	0.060	306.3	2.886	293.5	1.30	25.526	-65.888
Oct	07	1700	270.0	-2.7	267.3	23.00	120.08	0.061	304.6	2.955	292.5	1.26	25.489	-67.102
Oct	08	0600	247.5	-2.5	245.0	5.00	26.10	0.062	304.7	2.989	292.0	2.18	25.416	-67.366
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.065	304.9	3.051	290.8	2.17	25.233	-67.978
Oct	09	1200	225.0	-1.9	223.1	5.00	26.10	0.067	305.4	3.081	290.2	2.84	25.075	-68.173
Oct	10	0600	281.2	-1.5	279.7	15.50	80.92	0.068	307.0	3.035	288.8	0.48	25.223	-68.999
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.096	303.7	3.322	280.1	1.79	24.183	-71.863
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.102	304.5	3.360	276.3	1.59	23.737	-73.186
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.089	317.3	3.235	274.8	0.22	23.766	-74.359

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01e: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: used
Magnetic correction: not used
Current field: not used
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	0.0	270.0	9.00	46.99	0.000	0.0	0.000	0.0	0.00	28.005	-17.472
Sep	10	0600	270.0	0.0	270.0	45.00	234.94	0.000	0.0	0.000	0.0	0.00	28.005	-19.874
Sep	11	0600	270.0	0.0	270.0	60.00	313.25	0.000	0.0	0.000	0.0	0.00	28.005	-23.076
Sep	12	0600	270.0	0.0	270.0	40.00	208.83	0.000	0.0	0.000	0.0	0.00	28.005	-25.210
Sep	13	0600	270.0	0.0	270.0	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.005	-26.971
Sep	14	0600	270.0	0.0	270.0	33.00	172.29	0.000	0.0	0.000	0.0	0.00	28.005	-28.732
Sep	15	0600	270.0	0.0	270.0	20.00	104.42	0.000	0.0	0.000	0.0	0.00	28.005	-29.799
Sep	16	0600	270.0	0.0	270.0	27.00	140.96	0.000	0.0	0.000	0.0	0.00	28.005	-31.240
Sep	17	0600	270.0	0.0	270.0	39.00	203.61	0.000	0.0	0.000	0.0	0.00	28.005	-33.322
Sep	18	0600	270.0	0.0	270.0	50.00	261.04	0.000	0.0	0.000	0.0	0.00	28.005	-35.990
Sep	19	0600	270.0	0.0	270.0	55.00	287.14	0.000	0.0	0.000	0.0	0.00	28.005	-38.925
Sep	20	0600	270.0	0.0	270.0	25.00	130.52	0.000	0.0	0.000	0.0	0.00	28.005	-40.259
Sep	20	1800	281.2	0.0	281.2	3.80	19.84	0.000	0.0	0.000	0.0	0.00	28.040	-40.458
Sep	21	0600	292.5	0.0	292.5	3.80	19.84	0.000	0.0	0.000	0.0	0.00	28.108	-40.645
Sep	22	0600	270.0	0.0	270.0	13.00	67.87	0.000	0.0	0.000	0.0	0.00	28.108	-41.340
Sep	23	0600	292.5	0.0	292.5	30.00	156.62	0.000	0.0	0.000	0.0	0.00	28.649	-42.823
Sep	23	1800	315.0	0.0	315.0	13.50	70.48	0.000	0.0	0.000	0.0	0.00	29.098	-43.336
Sep	24	0100	326.2	0.0	326.2	8.10	42.29	0.000	0.0	0.000	0.0	0.00	29.415	-43.579
Sep	24	0600	270.0	0.0	270.0	5.40	28.19	0.000	0.0	0.000	0.0	0.00	29.415	-43.871
Sep	25	0600	270.0	0.0	270.0	14.50	75.70	0.000	0.0	0.000	0.0	0.00	29.415	-44.655
Sep	25	1800	270.0	0.0	270.0	4.50	23.49	0.000	0.0	0.000	0.0	0.00	29.415	-44.899
Sep	26	0600	225.0	0.0	225.0	17.00	88.75	0.000	0.0	0.000	0.0	0.00	28.849	-45.546
Sep	26	1500	270.0	0.0	270.0	11.60	60.56	0.000	0.0	0.000	0.0	0.00	28.849	-46.170
Sep	27	0600	225.0	0.0	225.0	19.40	101.28	0.000	0.0	0.000	0.0	0.00	28.204	-46.905
Sep	28	0600	270.0	0.0	270.0	24.00	125.30	0.000	0.0	0.000	0.0	0.00	28.204	-48.188
Sep	29	0600	270.0	0.0	270.0	14.00	73.09	0.000	0.0	0.000	0.0	0.00	28.204	-48.937
Sep	30	0600	270.0	0.0	270.0	24.00	125.30	0.000	0.0	0.000	0.0	0.00	28.204	-50.220
Oct	01	0600	270.0	0.0	270.0	14.00	73.09	0.000	0.0	0.000	0.0	0.00	28.204	-50.968
Oct	02	0600	270.0	0.0	270.0	25.00	130.52	0.000	0.0	0.000	0.0	0.00	28.204	-52.305
Oct	03	0600	270.0	0.0	270.0	39.00	203.61	0.000	0.0	0.000	0.0	0.00	28.204	-54.390
Oct	04	0600	270.0	0.0	270.0	47.00	245.38	0.000	0.0	0.000	0.0	0.00	28.204	-56.903
Oct	05	0600	270.0	0.0	270.0	63.00	328.91	0.000	0.0	0.000	0.0	0.00	28.204	-60.271
Oct	06	0600	270.0	0.0	270.0	57.00	297.58	0.000	0.0	0.000	0.0	0.00	28.204	-63.319
Oct	07	0600	270.0	0.0	270.0	40.00	208.83	0.000	0.0	0.000	0.0	0.00	28.204	-65.457
Oct	07	1700	270.0	0.0	270.0	23.00	120.08	0.000	0.0	0.000	0.0	0.00	28.204	-66.687
Oct	08	0600	247.5	0.0	247.5	5.00	26.10	0.000	0.0	0.000	0.0	0.00	28.113	-66.934
Oct	09	0600	247.5	0.0	247.5	11.80	61.61	0.000	0.0	0.000	0.0	0.00	27.901	-67.515
Oct	09	1200	225.0	0.0	225.0	5.00	26.10	0.000	0.0	0.000	0.0	0.00	27.734	-67.703
Oct	10	0600	281.2	0.0	281.2	15.50	80.92	0.000	0.0	0.000	0.0	0.00	27.876	-68.513
Oct	11	0600	247.5	0.0	247.5	59.00	308.03	0.000	0.0	0.000	0.0	0.00	26.813	-71.403
Oct	11	1800	247.5	0.0	247.5	27.00	140.96	0.000	0.0	0.000	0.0	0.00	26.326	-72.717
Oct	12	0200	270.0	0.0	270.0	22.50	117.47	0.000	0.0	0.000	0.0	0.00	26.326	-73.900

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01f: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep 09	0600	270.0	2.4	272.4	9.00	46.99	0.084	221.8	4.426	209.1	3.95	27.921	-17.528
Sep 10	0600	270.0	2.0	272.0	45.00	234.94	0.089	231.6	3.669	215.2	3.07	27.915	-19.983
Sep 11	0600	270.0	1.3	271.3	60.00	313.25	0.089	243.1	3.021	228.7	2.05	27.932	-23.251
Sep 12	0600	270.0	0.8	270.8	40.00	208.83	0.075	239.4	2.897	237.1	1.61	27.916	-25.447
Sep 13	0600	270.0	0.5	270.5	33.00	172.29	0.065	235.9	2.722	242.8	1.26	27.889	-27.259
Sep 14	0600	270.0	0.1	270.1	33.00	172.29	0.062	241.7	2.657	247.0	1.04	27.858	-29.064
Sep 15	0600	270.0	-0.1	269.9	20.00	104.42	0.061	247.1	2.702	247.8	1.02	27.826	-30.179
Sep 16	0600	270.0	-0.5	269.5	27.00	140.96	0.063	254.1	2.752	249.1	0.96	27.793	-31.669
Sep 17	0600	270.0	-1.2	268.8	39.00	203.61	0.061	256.1	2.676	254.0	0.69	27.745	-33.799
Sep 18	0600	270.0	-2.2	267.8	50.00	261.04	0.054	251.7	2.487	262.0	0.25	27.659	-36.507
Sep 19	0600	270.0	-3.4	266.6	55.00	287.14	0.047	254.5	2.438	268.7	0.09	27.519	-39.470
Sep 20	0600	270.0	-3.9	266.1	25.00	130.52	0.044	258.1	2.515	269.2	0.14	27.438	-40.833
Sep 20	1800	281.2	-4.0	277.2	3.80	19.84	0.043	258.6	2.517	269.4	0.34	27.455	-41.052
Sep 21	0600	292.5	-4.1	288.4	3.80	19.84	0.042	258.9	2.498	269.8	0.80	27.504	-41.264
Sep 22	0600	270.0	-4.4	265.6	13.00	67.87	0.040	261.3	2.517	270.5	0.21	27.455	-41.988
Sep 23	0600	292.5	-5.3	287.2	30.00	156.62	0.034	265.4	2.404	274.2	0.54	27.873	-43.543
Sep 23	1800	315.0	-5.6	309.4	13.50	70.48	0.030	264.8	2.297	276.3	1.25	28.271	-44.117
Sep 24	0100	326.2	-5.9	320.3	8.10	42.29	0.028	262.7	2.183	277.6	1.48	28.561	-44.405
Sep 24	0600	270.0	-6.0	264.0	5.40	28.19	0.028	263.7	2.184	277.9	0.53	28.535	-44.698
Sep 25	0600	270.0	-6.3	263.7	14.50	75.70	0.028	267.2	2.212	278.6	0.57	28.466	-45.496
Sep 25	1800	270.0	-6.4	263.6	4.50	23.49	0.028	268.3	2.221	278.8	0.58	28.445	-45.749
Sep 26	0600	225.0	-6.4	218.6	17.00	88.75	0.033	278.5	2.443	278.0	2.10	27.828	-46.338
Sep 26	1500	270.0	-6.6	263.4	11.60	60.56	0.034	282.4	2.467	278.9	0.66	27.771	-46.963
Sep 27	0600	225.0	-6.4	218.6	19.40	101.28	0.039	291.1	2.665	278.8	2.31	27.072	-47.635
Sep 28	0600	270.0	-6.8	263.2	24.00	125.30	0.039	289.1	2.620	281.2	0.81	26.961	-48.929
Sep 29	0600	270.0	-6.9	263.1	14.00	73.09	0.038	286.2	2.568	282.6	0.86	26.900	-49.697
Sep 30	0600	270.0	-7.2	262.8	24.00	125.30	0.038	281.6	2.491	284.9	0.94	26.778	-50.988
Oct 01	0600	270.0	-7.3	262.7	14.00	73.09	0.038	278.8	2.462	286.3	0.98	26.710	-51.755
Oct 02	0600	270.0	-7.4	262.6	25.00	130.52	0.039	281.0	2.426	288.6	1.06	26.575	-53.096
Oct 03	0600	270.0	-7.4	262.6	39.00	203.61	0.045	296.2	2.501	289.7	1.14	26.363	-55.168
Oct 04	0600	270.0	-7.3	262.7	47.00	245.38	0.053	308.3	2.664	289.8	1.21	26.114	-57.654
Oct 05	0600	270.0	-6.1	263.9	63.00	328.91	0.060	308.9	2.640	291.5	1.22	25.802	-60.972
Oct 06	0600	270.0	-4.4	265.6	57.00	297.58	0.061	308.5	2.774	292.9	1.27	25.601	-63.982
Oct 07	0600	270.0	-3.2	266.8	40.00	208.83	0.060	306.0	2.898	293.5	1.30	25.520	-66.110
Oct 07	1700	270.0	-2.5	267.5	23.00	120.08	0.061	304.6	2.967	292.2	1.24	25.485	-67.329
Oct 08	0600	247.5	-2.3	245.2	5.00	26.10	0.062	304.7	2.999	291.6	2.17	25.412	-67.595
Oct 09	0600	247.5	-1.9	245.6	11.80	61.61	0.066	305.3	3.048	290.4	2.15	25.231	-68.210
Oct 09	1200	225.0	-1.7	223.3	5.00	26.10	0.068	306.0	3.079	289.8	2.82	25.072	-68.406
Oct 10	0600	281.2	-1.4	279.8	15.50	80.92	0.068	304.8	3.034	288.3	0.45	25.222	-69.236
Oct 11	0600	247.5	0.2	247.7	59.00	308.03	0.098	304.5	3.314	279.5	1.75	24.183	-72.115
Oct 11	1800	247.5	0.6	248.1	27.00	140.96	0.097	306.6	3.334	275.9	1.56	23.737	-73.444
Oct 12	0200	270.0	0.9	270.9	22.50	117.47	0.092	321.1	3.202	274.5	0.20	23.768	-74.620

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01g: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: monthly
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.092	223.9	0.000	0.0	0.00	27.968	-17.530
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.096	234.9	0.000	0.0	0.00	27.998	-19.981
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.097	246.8	0.000	0.0	0.00	28.044	-23.243
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.087	239.7	0.000	0.0	0.00	28.046	-25.440
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.080	233.8	0.000	0.0	0.00	28.027	-27.255
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.071	240.9	0.000	0.0	0.00	28.002	-29.063
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.065	249.2	0.000	0.0	0.00	27.979	-30.179
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.062	261.7	0.000	0.0	0.00	27.960	-31.666
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.055	266.1	0.000	0.0	0.00	27.930	-33.788
Sep	18	0600	270.0	-2.2	267.8	50.00	261.04	0.041	257.1	0.000	0.0	0.00	27.854	-36.482
Sep	19	0600	270.0	-3.4	266.6	55.00	287.14	0.029	263.2	0.000	0.0	0.00	27.720	-39.423
Sep	20	0600	270.0	-4.0	266.0	25.00	130.52	0.025	272.9	0.000	0.0	0.00	27.643	-40.768
Sep	20	1800	281.2	-4.1	277.1	3.80	19.84	0.024	273.8	0.000	0.0	0.00	27.666	-40.978
Sep	21	0600	292.5	-4.2	288.3	3.80	19.84	0.023	273.5	0.000	0.0	0.00	27.723	-41.180
Sep	22	0600	270.0	-4.5	265.5	13.00	67.87	0.057	252.1	0.000	0.0	0.00	27.663	-41.914
Sep	23	0600	292.5	-5.3	287.2	30.00	156.62	0.045	258.1	0.000	0.0	0.00	28.078	-43.474
Sep	23	1800	315.0	-5.7	309.3	13.50	70.48	0.038	261.6	0.000	0.0	0.00	28.477	-44.047
Sep	24	0100	326.2	-5.9	320.3	8.10	42.29	0.034	263.7	0.000	0.0	0.00	28.769	-44.332
Sep	24	0600	270.0	-6.1	263.9	5.40	28.19	0.034	264.5	0.000	0.0	0.00	28.742	-44.626
Sep	25	0600	270.0	-6.4	263.6	14.50	75.70	0.034	266.7	0.000	0.0	0.00	28.666	-45.426
Sep	25	1800	270.0	-6.5	263.5	4.50	23.49	0.033	267.6	0.000	0.0	0.00	28.641	-45.680
Sep	26	0600	225.0	-6.4	218.6	17.00	88.75	0.037	270.3	0.000	0.0	0.00	28.018	-46.260
Sep	26	1500	270.0	-6.6	263.4	11.60	60.56	0.036	274.1	0.000	0.0	0.00	27.956	-46.884
Sep	27	0600	225.0	-6.5	218.5	19.40	101.28	0.038	279.6	0.000	0.0	0.00	27.246	-47.542
Sep	28	0600	270.0	-6.8	263.2	24.00	125.30	0.038	282.8	0.000	0.0	0.00	27.122	-48.831
Sep	29	0600	270.0	-7.0	263.0	14.00	73.09	0.039	283.6	0.000	0.0	0.00	27.049	-49.596
Sep	30	0600	270.0	-7.3	262.7	24.00	125.30	0.040	285.3	0.000	0.0	0.00	26.917	-50.882
Oct	01	0600	270.0	-7.4	262.6	14.00	73.09	0.041	286.3	0.000	0.0	0.00	26.842	-51.647
Oct	02	0600	270.0	-7.4	262.6	25.00	130.52	0.042	288.7	0.000	0.0	0.00	26.700	-52.983
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.045	294.6	0.000	0.0	0.00	26.477	-55.047
Oct	04	0600	270.0	-7.4	262.6	47.00	245.38	0.049	302.2	0.000	0.0	0.00	26.209	-57.521
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.057	300.4	0.000	0.0	0.00	25.875	-60.824
Oct	06	0600	270.0	-4.5	265.5	57.00	297.58	0.060	297.7	0.000	0.0	0.00	25.648	-63.824
Oct	07	0600	270.0	-3.3	266.7	40.00	208.83	0.059	295.9	0.000	0.0	0.00	25.542	-65.945
Oct	07	1700	270.0	-2.6	267.4	23.00	120.08	0.059	294.5	0.000	0.0	0.00	25.495	-67.160
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.060	294.4	0.000	0.0	0.00	25.407	-67.420
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.062	294.4	0.000	0.0	0.00	25.195	-68.024
Oct	09	1200	225.0	-1.8	223.2	5.00	26.10	0.064	294.7	0.000	0.0	0.00	25.029	-68.213
Oct	10	0600	281.2	-1.5	279.7	15.50	80.92	0.066	294.0	0.000	0.0	0.00	25.165	-69.042
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.106	286.5	0.000	0.0	0.00	24.092	-71.907
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.093	299.3	0.000	0.0	0.00	23.631	-73.230
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.085	301.6	0.000	0.0	0.00	23.655	-74.402

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 01h: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: monthly
Wind field: monthly Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.093	223.6	5.539	210.4	4.89	27.907	-17.533
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.098	235.1	4.780	218.7	3.83	27.889	-19.985
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.098	248.0	4.003	232.1	2.53	27.902	-23.246
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.085	240.3	3.568	237.2	1.98	27.881	-25.441
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.077	233.2	3.252	240.2	1.64	27.845	-27.251
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.069	240.5	3.097	243.0	1.41	27.804	-29.053
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.065	249.1	3.127	243.8	1.38	27.767	-30.167
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.065	261.2	3.160	245.8	1.27	27.734	-31.652
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.059	266.5	3.101	252.3	0.88	27.692	-33.773
Sep	18	0600	270.0	-2.1	267.9	50.00	261.04	0.044	262.6	3.066	262.6	0.28	27.614	-36.463
Sep	19	0600	270.0	-3.3	266.7	55.00	287.14	0.032	270.5	3.003	270.3	0.19	27.487	-39.401
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.028	279.1	3.005	271.6	0.29	27.418	-40.746
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.027	279.9	2.981	271.9	0.28	27.441	-40.957
Sep	21	0600	292.5	-4.1	288.4	3.80	19.84	0.025	279.9	2.944	272.5	0.81	27.495	-41.160
Sep	22	0600	270.0	-4.4	265.6	13.00	67.87	0.061	251.3	2.213	266.1	0.02	27.434	-41.896
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.049	257.2	2.208	269.2	0.69	27.842	-43.458
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.041	260.7	2.112	270.7	1.32	28.237	-44.035
Sep	24	0100	326.2	-5.8	320.4	8.10	42.29	0.037	262.7	1.998	271.3	1.51	28.525	-44.324
Sep	24	0600	270.0	-6.0	264.0	5.40	28.19	0.037	263.6	1.999	271.7	0.27	28.499	-44.618
Sep	25	0600	270.0	-6.3	263.7	14.50	75.70	0.036	266.4	2.069	272.7	0.32	28.427	-45.419
Sep	25	1800	270.0	-6.4	263.6	4.50	23.49	0.035	267.5	2.104	273.0	0.34	28.405	-45.673
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.038	270.6	2.355	273.7	1.93	27.789	-46.263
Sep	26	1500	270.0	-6.5	263.5	11.60	60.56	0.037	274.8	2.380	274.8	0.46	27.730	-46.887
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.039	280.6	2.581	275.7	2.17	27.030	-47.558
Sep	28	0600	270.0	-6.7	263.3	24.00	125.30	0.040	284.3	2.543	278.3	0.66	26.915	-48.846
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.040	285.2	2.484	279.8	0.71	26.853	-49.612
Sep	30	0600	270.0	-7.2	262.8	24.00	125.30	0.042	286.7	2.305	282.6	0.78	26.731	-50.899
Oct	01	0600	270.0	-7.3	262.7	14.00	73.09	0.042	287.6	2.234	284.5	0.83	26.667	-51.664
Oct	02	0600	270.0	-7.3	262.7	25.00	130.52	0.043	290.0	2.140	287.8	0.91	26.538	-53.001
Oct	03	0600	270.0	-7.3	262.7	39.00	203.61	0.045	296.3	2.235	290.3	1.04	26.329	-55.063
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.049	304.1	2.383	289.7	1.08	26.078	-57.536
Oct	05	0600	270.0	-6.1	263.9	63.00	328.91	0.057	301.6	2.293	287.0	0.90	25.761	-60.837
Oct	06	0600	270.0	-4.4	265.6	57.00	297.58	0.060	298.4	2.422	285.1	0.81	25.548	-63.836
Oct	07	0600	270.0	-3.2	266.8	40.00	208.83	0.059	296.2	2.654	285.5	0.85	25.454	-65.956
Oct	07	1700	270.0	-2.6	267.4	23.00	120.08	0.059	294.7	2.780	284.3	0.81	25.412	-67.170
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.060	294.6	2.813	283.9	1.76	25.333	-67.435
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.062	294.5	2.874	283.1	1.75	25.139	-68.048
Oct	09	1200	225.0	-1.8	223.2	5.00	26.10	0.064	294.8	2.925	282.9	2.52	24.978	-68.243
Oct	10	0600	281.2	-1.4	279.8	15.50	80.92	0.066	293.7	2.966	280.9	0.06	25.116	-69.072
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.108	287.0	3.275	274.0	1.46	24.060	-71.945
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.093	299.1	3.253	269.8	1.20	23.606	-73.270
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.086	301.8	3.123	266.2	0.25	23.630	-74.442

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 02b: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: monthly Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep 09	0600	270.0	2.4	272.4	9.00	46.99	0.084	221.8	5.539	210.3	4.89	27.910	-17.526
Sep 10	0600	270.0	2.0	272.0	45.00	234.94	0.090	231.6	4.783	218.6	3.84	27.895	-19.970
Sep 11	0600	270.0	1.3	271.3	60.00	313.25	0.090	243.3	4.006	232.1	2.53	27.905	-23.222
Sep 12	0600	270.0	0.8	270.8	40.00	208.83	0.076	239.5	3.573	237.1	1.98	27.885	-25.408
Sep 13	0600	270.0	0.5	270.5	33.00	172.29	0.065	235.8	3.253	240.2	1.64	27.854	-27.211
Sep 14	0600	270.0	0.1	270.1	33.00	172.29	0.062	241.2	3.092	243.0	1.41	27.820	-29.007
Sep 15	0600	270.0	-0.1	269.9	20.00	104.42	0.061	246.7	3.115	243.8	1.37	27.784	-30.116
Sep 16	0600	270.0	-0.4	269.6	27.00	140.96	0.063	253.7	3.158	245.7	1.28	27.747	-31.598
Sep 17	0600	270.0	-1.1	268.9	39.00	203.61	0.061	256.2	3.102	252.1	0.89	27.698	-33.717
Sep 18	0600	270.0	-2.1	267.9	50.00	261.04	0.055	252.1	3.067	262.4	0.29	27.612	-36.412
Sep 19	0600	270.0	-3.3	266.7	55.00	287.14	0.047	254.6	3.009	270.2	0.18	27.477	-39.361
Sep 20	0600	270.0	-3.8	266.2	25.00	130.52	0.044	258.1	3.017	271.5	0.28	27.398	-40.718
Sep 20	1800	281.2	-3.9	277.3	3.80	19.84	0.043	258.5	2.995	271.8	0.28	27.415	-40.936
Sep 21	0600	292.5	-4.0	288.5	3.80	19.84	0.042	258.8	2.960	272.3	0.82	27.464	-41.147
Sep 22	0600	270.0	-4.3	265.7	13.00	67.87	0.041	261.1	2.219	266.0	0.01	27.414	-41.868
Sep 23	0600	292.5	-5.2	287.3	30.00	156.62	0.034	265.2	2.209	269.1	0.69	27.831	-43.416
Sep 23	1800	315.0	-5.6	309.4	13.50	70.48	0.030	264.7	2.112	270.6	1.32	28.228	-43.988
Sep 24	0100	326.2	-5.8	320.4	8.10	42.29	0.028	262.8	2.001	271.3	1.51	28.517	-44.274
Sep 24	0600	270.0	-5.9	264.1	5.40	28.19	0.028	263.8	2.002	271.6	0.26	28.491	-44.566
Sep 25	0600	270.0	-6.2	263.8	14.50	75.70	0.028	267.4	2.066	272.6	0.32	28.420	-45.360
Sep 25	1800	270.0	-6.3	263.7	4.50	23.49	0.029	268.6	2.100	273.0	0.34	28.398	-45.612
Sep 26	0600	225.0	-6.3	218.7	17.00	88.75	0.033	278.3	2.357	273.6	1.93	27.783	-46.199
Sep 26	1500	270.0	-6.5	263.5	11.60	60.56	0.034	282.3	2.381	274.6	0.46	27.726	-46.821
Sep 27	0600	225.0	-6.4	218.6	19.40	101.28	0.040	291.3	2.581	275.5	2.16	27.029	-47.491
Sep 28	0600	270.0	-6.7	263.3	24.00	125.30	0.040	289.7	2.548	278.1	0.65	26.919	-48.779
Sep 29	0600	270.0	-6.9	263.1	14.00	73.09	0.039	287.0	2.489	279.7	0.71	26.858	-49.544
Sep 30	0600	270.0	-7.2	262.8	24.00	125.30	0.039	282.4	2.318	282.4	0.78	26.736	-50.829
Oct 01	0600	270.0	-7.2	262.8	14.00	73.09	0.039	279.7	2.241	284.3	0.82	26.668	-51.592
Oct 02	0600	270.0	-7.3	262.7	25.00	130.52	0.040	280.6	2.149	287.6	0.91	26.534	-52.927
Oct 03	0600	270.0	-7.3	262.7	39.00	203.61	0.045	295.2	2.233	290.2	1.03	26.322	-54.989
Oct 04	0600	270.0	-7.3	262.7	47.00	245.38	0.053	308.0	2.384	289.7	1.08	26.073	-57.463
Oct 05	0600	270.0	-6.2	263.8	63.00	328.91	0.060	309.2	2.301	287.1	0.91	25.760	-60.764
Oct 06	0600	270.0	-4.5	265.5	57.00	297.58	0.061	309.1	2.416	285.1	0.81	25.552	-63.758
Oct 07	0600	270.0	-3.3	266.7	40.00	208.83	0.061	306.4	2.643	285.5	0.85	25.464	-65.874
Oct 07	1700	270.0	-2.6	267.4	23.00	120.08	0.061	304.6	2.773	284.4	0.81	25.425	-67.087
Oct 08	0600	247.5	-2.4	245.1	5.00	26.10	0.062	304.7	2.805	284.0	1.76	25.351	-67.350
Oct 09	0600	247.5	-2.0	245.5	11.80	61.61	0.065	304.9	2.865	283.2	1.75	25.165	-67.960
Oct 09	1200	225.0	-1.8	223.2	5.00	26.10	0.067	305.5	2.909	283.1	2.52	25.006	-68.154
Oct 10	0600	281.2	-1.5	279.7	15.50	80.92	0.069	307.2	2.952	281.1	0.07	25.151	-68.981
Oct 11	0600	247.5	0.1	247.6	59.00	308.03	0.098	303.9	3.260	274.3	1.47	24.108	-71.842
Oct 11	1800	247.5	0.6	248.1	27.00	140.96	0.103	303.4	3.253	270.1	1.22	23.661	-73.165
Oct 12	0200	270.0	0.9	270.9	22.50	117.47	0.088	315.5	3.127	266.6	0.23	23.688	-74.337

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 02d: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: monthly
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.092	223.7	4.427	209.1	3.95	27.918	-17.533
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.097	235.1	3.671	215.2	3.07	27.910	-19.984
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.098	247.8	3.023	228.6	2.05	27.930	-23.246
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.086	240.2	2.899	237.1	1.61	27.913	-25.441
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.078	233.3	2.726	242.8	1.27	27.880	-27.252
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.069	240.6	2.663	247.0	1.05	27.843	-29.055
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.065	249.1	2.709	247.8	1.02	27.810	-30.169
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.064	261.3	2.761	249.1	0.97	27.780	-31.655
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.058	266.4	2.681	253.9	0.69	27.741	-33.776
Sep	18	0600	270.0	-2.2	267.8	50.00	261.04	0.043	261.6	2.485	261.9	0.26	27.664	-36.467
Sep	19	0600	270.0	-3.4	266.6	55.00	287.14	0.031	269.1	2.430	268.7	0.09	27.535	-39.406
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.027	277.9	2.500	269.3	0.14	27.463	-40.750
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.026	278.8	2.503	269.4	0.34	27.485	-40.961
Sep	21	0600	292.5	-4.1	288.4	3.80	19.84	0.025	278.7	2.484	269.8	0.79	27.539	-41.165
Sep	22	0600	270.0	-4.4	265.6	13.00	67.87	0.060	251.5	2.506	270.4	0.21	27.481	-41.900
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.048	257.3	2.390	274.1	0.54	27.890	-43.462
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.040	260.9	2.292	276.2	1.25	28.284	-44.039
Sep	24	0100	326.2	-5.9	320.3	8.10	42.29	0.036	262.9	2.178	277.5	1.48	28.573	-44.328
Sep	24	0600	270.0	-6.0	264.0	5.40	28.19	0.036	263.8	2.179	277.9	0.52	28.547	-44.622
Sep	25	0600	270.0	-6.3	263.7	14.50	75.70	0.035	266.5	2.207	278.6	0.57	28.478	-45.423
Sep	25	1800	270.0	-6.4	263.6	4.50	23.49	0.035	267.5	2.216	278.8	0.58	28.457	-45.678
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.038	270.6	2.440	277.9	2.10	27.841	-46.268
Sep	26	1500	270.0	-6.5	263.5	11.60	60.56	0.037	274.6	2.464	278.8	0.65	27.783	-46.892
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.038	280.4	2.662	278.7	2.31	27.083	-47.564
Sep	28	0600	270.0	-6.7	263.3	24.00	125.30	0.039	283.9	2.626	281.1	0.80	26.969	-48.852
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.040	284.8	2.572	282.4	0.85	26.907	-49.618
Sep	30	0600	270.0	-7.2	262.8	24.00	125.30	0.041	286.3	2.496	284.7	0.93	26.786	-50.906
Oct	01	0600	270.0	-7.3	262.7	14.00	73.09	0.042	287.2	2.462	286.1	0.98	26.723	-51.671
Oct	02	0600	270.0	-7.4	262.6	25.00	130.52	0.043	289.6	2.421	288.5	1.06	26.595	-53.008
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.045	295.7	2.485	289.8	1.13	26.386	-55.072
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.049	303.3	2.658	289.8	1.21	26.134	-57.547
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.057	301.0	2.639	291.4	1.22	25.816	-60.849
Oct	06	0600	270.0	-4.4	265.6	57.00	297.58	0.060	298.0	2.765	292.9	1.27	25.605	-63.850
Oct	07	0600	270.0	-3.3	266.8	40.00	208.83	0.059	295.9	2.893	293.5	1.30	25.515	-65.971
Oct	07	1700	270.0	-2.6	267.4	23.00	120.08	0.059	294.5	2.963	292.4	1.25	25.475	-67.186
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.060	294.4	2.997	291.8	2.18	25.398	-67.453
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.062	294.3	3.056	290.6	2.17	25.208	-68.067
Oct	09	1200	225.0	-1.8	223.2	5.00	26.10	0.064	294.7	3.086	290.0	2.84	25.047	-68.263
Oct	10	0600	281.2	-1.4	279.8	15.50	80.92	0.065	293.2	3.045	288.6	0.47	25.188	-69.091
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.105	286.6	3.339	279.8	1.78	24.135	-71.966
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.092	299.2	3.365	276.0	1.58	23.682	-73.292
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.087	303.0	3.237	274.5	0.21	23.708	-74.465

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 02e: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: September
Wind field: September Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep 09	0600	270.0	2.4	272.4	9.00	46.99	0.093	223.6	5.539	210.4	4.89	27.907	-17.533
Sep 10	0600	270.0	2.0	272.0	45.00	234.94	0.098	235.1	4.780	218.7	3.83	27.889	-19.985
Sep 11	0600	270.0	1.3	271.3	60.00	313.25	0.098	248.0	4.003	232.1	2.53	27.902	-23.246
Sep 12	0600	270.0	0.8	270.8	40.00	208.83	0.085	240.3	3.568	237.2	1.98	27.881	-25.441
Sep 13	0600	270.0	0.5	270.5	33.00	172.29	0.077	233.2	3.252	240.2	1.64	27.845	-27.251
Sep 14	0600	270.0	0.1	270.1	33.00	172.29	0.069	240.5	3.097	243.0	1.41	27.804	-29.053
Sep 15	0600	270.0	-0.1	269.9	20.00	104.42	0.065	249.1	3.127	243.8	1.38	27.767	-30.167
Sep 16	0600	270.0	-0.5	269.5	27.00	140.96	0.065	261.2	3.160	245.8	1.27	27.734	-31.652
Sep 17	0600	270.0	-1.2	268.8	39.00	203.61	0.059	266.5	3.101	252.3	0.88	27.692	-33.773
Sep 18	0600	270.0	-2.1	267.9	50.00	261.04	0.044	262.6	3.066	262.6	0.28	27.614	-36.463
Sep 19	0600	270.0	-3.3	266.7	55.00	287.14	0.032	270.5	3.003	270.3	0.19	27.487	-39.401
Sep 20	0600	270.0	-3.9	266.1	25.00	130.52	0.028	279.1	3.005	271.6	0.29	27.418	-40.746
Sep 20	1800	281.2	-4.0	277.2	3.80	19.84	0.027	279.9	2.981	271.9	0.28	27.441	-40.957
Sep 21	0600	292.5	-4.1	288.4	3.80	19.84	0.025	279.9	2.944	272.5	0.81	27.495	-41.160
Sep 22	0600	270.0	-4.4	265.6	13.00	67.87	0.024	285.9	2.923	273.5	0.40	27.458	-41.867
Sep 23	0600	292.5	-5.2	287.3	30.00	156.62	0.021	283.0	2.649	278.0	0.43	27.884	-43.401
Sep 23	1800	315.0	-5.6	309.4	13.50	70.48	0.019	271.7	2.491	280.8	1.19	28.284	-43.967
Sep 24	0100	326.2	-5.8	320.4	8.10	42.29	0.018	261.2	2.376	282.6	1.46	28.573	-44.251
Sep 24	0600	270.0	-6.0	264.0	5.40	28.19	0.019	262.1	2.377	282.9	0.77	28.549	-44.542
Sep 25	0600	270.0	-6.3	263.7	14.50	75.70	0.020	266.8	2.403	283.5	0.81	28.483	-45.329
Sep 25	1800	270.0	-6.4	263.6	4.50	23.49	0.021	268.0	2.411	283.7	0.83	28.464	-45.578
Sep 26	0600	225.0	-6.3	218.7	17.00	88.75	0.028	287.7	2.637	281.6	2.35	27.851	-46.164
Sep 26	1500	270.0	-6.5	263.5	11.60	60.56	0.031	290.1	2.659	282.2	0.85	27.796	-46.785
Sep 27	0600	225.0	-6.4	218.6	19.40	101.28	0.041	300.7	2.818	281.3	2.50	27.103	-47.456
Sep 28	0600	270.0	-6.7	263.3	24.00	125.30	0.039	295.6	2.799	283.4	0.96	26.999	-48.744
Sep 29	0600	270.0	-6.9	263.1	14.00	73.09	0.037	289.4	2.770	284.6	1.02	26.943	-49.507
Sep 30	0600	270.0	-7.2	262.8	24.00	125.30	0.035	277.6	2.769	286.4	1.11	26.823	-50.791
Oct 01	0600	270.0	-7.3	262.7	14.00	73.09	0.034	270.2	2.755	287.4	1.15	26.754	-51.552
Oct 02	0600	270.0	-7.4	262.6	25.00	130.52	0.036	269.0	2.755	288.9	1.22	26.616	-52.886
Oct 03	0600	270.0	-7.4	262.6	39.00	203.61	0.044	294.2	2.835	289.4	1.28	26.402	-54.948
Oct 04	0600	270.0	-7.3	262.7	47.00	245.38	0.057	311.8	2.940	289.8	1.34	26.155	-57.424
Oct 05	0600	270.0	-6.3	263.7	63.00	328.91	0.062	315.8	3.028	294.6	1.55	25.848	-60.727
Oct 06	0600	270.0	-4.6	265.4	57.00	297.58	0.064	318.6	3.144	298.8	1.73	25.651	-63.719
Oct 07	0600	270.0	-3.4	266.6	40.00	208.83	0.064	315.7	3.182	300.3	1.77	25.577	-65.834
Oct 07	1700	270.0	-2.7	267.3	23.00	120.08	0.064	313.8	3.188	300.0	1.72	25.545	-67.046
Oct 08	0600	247.5	-2.5	245.0	5.00	26.10	0.065	313.9	3.201	299.4	2.60	25.478	-67.310
Oct 09	0600	247.5	-2.1	245.4	11.80	61.61	0.068	314.3	3.235	298.0	2.57	25.308	-67.921
Oct 09	1200	225.0	-1.9	223.1	5.00	26.10	0.071	314.7	3.264	297.1	3.14	25.151	-68.115
Oct 10	0600	281.2	-1.6	279.6	15.50	80.92	0.073	317.7	3.209	296.5	0.93	25.309	-68.938
Oct 11	0600	247.5	0.0	247.5	59.00	308.03	0.095	321.5	3.401	286.3	2.13	24.285	-71.796
Oct 11	1800	247.5	0.5	248.0	27.00	140.96	0.112	310.2	3.460	282.7	1.97	23.847	-73.116
Oct 12	0200	270.0	0.8	270.8	22.50	117.47	0.103	331.2	3.334	283.1	0.71	23.884	-74.288

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 02f: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: October
Wind field: October Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.076	219.5	3.369	207.1	3.06	27.935	-17.518
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.082	227.3	2.567	208.5	2.30	27.940	-19.954
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.082	237.4	2.041	221.3	1.56	27.962	-23.198
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.065	238.4	2.224	236.4	1.26	27.950	-25.377
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.053	239.7	2.219	246.0	0.92	27.933	-27.173
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.054	243.0	2.234	252.2	0.69	27.913	-28.964
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.058	244.8	2.346	252.9	0.69	27.886	-30.070
Sep	16	0600	270.0	-0.4	269.6	27.00	140.96	0.064	246.9	2.350	253.2	0.66	27.854	-31.552
Sep	17	0600	270.0	-1.1	268.9	39.00	203.61	0.067	247.5	2.262	255.9	0.51	27.802	-33.673
Sep	18	0600	270.0	-2.1	267.9	50.00	261.04	0.067	245.7	1.974	260.1	0.27	27.710	-36.375
Sep	19	0600	270.0	-3.3	266.7	55.00	287.14	0.064	247.1	1.942	265.9	0.03	27.564	-39.336
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.062	249.1	2.078	265.7	0.02	27.471	-40.706
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.061	249.6	2.099	265.7	0.42	27.483	-40.931
Sep	21	0600	292.5	-4.1	288.4	3.80	19.84	0.060	250.1	2.103	265.8	0.81	27.527	-41.148
Sep	22	0600	270.0	-4.4	265.6	13.00	67.87	0.060	251.4	2.199	266.1	0.02	27.467	-41.883
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.048	257.2	2.194	269.2	0.68	27.875	-43.446
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.041	260.7	2.099	270.7	1.31	28.270	-44.023
Sep	24	0100	326.2	-5.8	320.4	8.10	42.29	0.037	262.8	1.985	271.3	1.50	28.558	-44.312
Sep	24	0600	270.0	-6.0	264.0	5.40	28.19	0.036	263.7	1.986	271.7	0.26	28.532	-44.605
Sep	25	0600	270.0	-6.3	263.7	14.50	75.70	0.036	266.4	2.054	272.7	0.32	28.460	-45.407
Sep	25	1800	270.0	-6.4	263.6	4.50	23.49	0.035	267.4	2.089	273.0	0.34	28.438	-45.661
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.038	270.5	2.346	273.7	1.92	27.821	-46.251
Sep	26	1500	270.0	-6.5	263.5	11.60	60.56	0.037	274.6	2.370	274.8	0.46	27.763	-46.874
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.039	280.4	2.569	275.7	2.16	27.062	-47.546
Sep	28	0600	270.0	-6.7	263.3	24.00	125.30	0.039	284.1	2.534	278.3	0.66	26.947	-48.834
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.040	284.9	2.476	279.8	0.71	26.884	-49.600
Sep	30	0600	270.0	-7.2	262.8	24.00	125.30	0.042	286.4	2.298	282.6	0.78	26.762	-50.887
Oct	01	0600	270.0	-7.3	262.7	14.00	73.09	0.042	287.4	2.226	284.5	0.82	26.698	-51.652
Oct	02	0600	270.0	-7.3	262.7	25.00	130.52	0.043	289.8	2.133	287.8	0.91	26.568	-52.989
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.045	295.9	2.228	290.3	1.03	26.358	-55.052
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.049	303.7	2.378	289.7	1.08	26.107	-57.526
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.057	301.3	2.286	287.0	0.90	25.787	-60.827
Oct	06	0600	270.0	-4.4	265.6	57.00	297.58	0.060	298.2	2.413	285.1	0.81	25.573	-63.826
Oct	07	0600	270.0	-3.2	266.8	40.00	208.83	0.059	296.1	2.646	285.5	0.85	25.478	-65.947
Oct	07	1700	270.0	-2.6	267.4	23.00	120.08	0.059	294.6	2.773	284.3	0.80	25.436	-67.161
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.060	294.5	2.806	283.8	1.76	25.357	-67.427
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.062	294.4	2.869	283.1	1.75	25.163	-68.039
Oct	09	1200	225.0	-1.8	223.2	5.00	26.10	0.064	294.8	2.918	282.9	2.52	25.002	-68.234
Oct	10	0600	281.2	-1.4	279.8	15.50	80.92	0.066	293.7	2.959	280.9	0.06	25.139	-69.063
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.107	286.8	3.268	274.0	1.45	24.083	-71.936
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.093	299.2	3.249	269.8	1.20	23.629	-73.261
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.086	302.0	3.120	266.3	0.25	23.652	-74.433

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 04b: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.005
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.084	221.9	4.415	209.1	3.95	27.953	-17.524
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.089	231.4	3.647	215.0	3.06	27.972	-19.968
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.089	242.7	2.981	228.5	2.03	28.006	-23.221
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.076	239.3	2.862	237.0	1.59	28.002	-25.409
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.066	236.2	2.688	242.7	1.25	27.985	-27.214
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.063	241.8	2.615	246.9	1.03	27.962	-29.013
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.062	247.1	2.641	247.8	0.99	27.937	-30.124
Sep	16	0600	270.0	-0.5	269.5	27.00	140.96	0.063	254.1	2.691	249.1	0.94	27.911	-31.609
Sep	17	0600	270.0	-1.2	268.8	39.00	203.61	0.061	256.2	2.608	254.0	0.67	27.870	-33.732
Sep	18	0600	270.0	-2.2	267.8	50.00	261.04	0.054	251.1	2.417	262.0	0.25	27.787	-36.430
Sep	19	0600	270.0	-3.4	266.6	55.00	287.14	0.046	253.4	2.374	269.0	0.10	27.648	-39.382
Sep	20	0600	270.0	-3.9	266.1	25.00	130.52	0.043	257.1	2.456	269.6	0.15	27.565	-40.740
Sep	20	1800	281.2	-4.0	277.2	3.80	19.84	0.042	257.6	2.463	269.7	0.32	27.583	-40.957
Sep	21	0600	292.5	-4.1	288.4	3.80	19.84	0.041	257.9	2.446	270.1	0.77	27.635	-41.166
Sep	22	0600	270.0	-4.4	265.6	13.00	67.87	0.039	260.3	2.465	270.7	0.22	27.584	-41.887
Sep	23	0600	292.5	-5.3	287.2	30.00	156.62	0.033	264.1	2.342	274.5	0.52	28.004	-43.434
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.029	263.1	2.242	276.6	1.21	28.404	-44.004
Sep	24	0100	326.2	-5.9	320.3	8.10	42.29	0.026	260.8	2.129	277.9	1.44	28.695	-44.288
Sep	24	0600	270.0	-6.0	264.0	5.40	28.19	0.026	261.6	2.131	278.2	0.53	28.668	-44.580
Sep	25	0600	270.0	-6.3	263.7	14.50	75.70	0.027	264.9	2.161	278.9	0.57	28.595	-45.374
Sep	25	1800	270.0	-6.4	263.6	4.50	23.49	0.027	266.0	2.170	279.1	0.58	28.571	-45.625
Sep	26	0600	225.0	-6.4	218.6	17.00	88.75	0.032	276.4	2.407	278.1	2.07	27.951	-46.206
Sep	26	1500	270.0	-6.6	263.4	11.60	60.56	0.033	280.2	2.431	278.9	0.65	27.892	-46.828
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.038	289.8	2.626	278.7	2.28	27.188	-47.490
Sep	28	0600	270.0	-6.8	263.2	24.00	125.30	0.038	289.0	2.600	281.1	0.80	27.072	-48.778
Sep	29	0600	270.0	-7.0	263.0	14.00	73.09	0.037	286.5	2.545	282.5	0.85	27.005	-49.542
Sep	30	0600	270.0	-7.3	262.7	24.00	125.30	0.037	281.7	2.468	284.8	0.93	26.876	-50.826
Oct	01	0600	270.0	-7.3	262.7	14.00	73.09	0.037	278.9	2.432	286.2	0.97	26.801	-51.588
Oct	02	0600	270.0	-7.4	262.6	25.00	130.52	0.038	279.7	2.408	288.5	1.05	26.659	-52.922
Oct	03	0600	270.0	-7.4	262.6	39.00	203.61	0.044	294.8	2.466	289.9	1.13	26.438	-54.984
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.053	307.8	2.644	289.9	1.21	26.179	-57.458
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.059	308.6	2.632	291.4	1.22	25.855	-60.760
Oct	06	0600	270.0	-4.5	265.5	57.00	297.58	0.061	308.5	2.751	292.9	1.27	25.639	-63.756
Oct	07	0600	270.0	-3.3	266.7	40.00	208.83	0.060	306.2	2.881	293.5	1.30	25.544	-65.873
Oct	07	1700	270.0	-2.7	267.3	23.00	120.08	0.061	304.6	2.950	292.6	1.26	25.503	-67.086
Oct	08	0600	247.5	-2.5	245.0	5.00	26.10	0.062	304.7	2.986	292.0	2.18	25.422	-67.347
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.065	304.9	3.052	290.9	2.17	25.226	-67.952
Oct	09	1200	225.0	-1.9	223.1	5.00	26.10	0.067	305.4	3.083	290.3	2.84	25.064	-68.142
Oct	10	0600	281.2	-1.5	279.7	15.50	80.92	0.069	307.0	3.039	288.8	0.48	25.209	-68.969
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.096	303.7	3.332	280.1	1.79	24.156	-71.827
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.103	303.8	3.373	276.3	1.59	23.705	-73.148
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.088	316.1	3.249	274.8	0.22	23.733	-74.320

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 04c: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumanl Leeway wind factor: 0.010
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon	Da Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09 0600	270.0	2.4	272.4	9.00	46.99	0.084	221.9	4.421	209.1	3.95	27.935	-17.525
Sep	10 0600	270.0	2.0	272.0	45.00	234.94	0.089	231.5	3.662	215.1	3.07	27.941	-19.968
Sep	11 0600	270.0	1.3	271.3	60.00	313.25	0.089	242.9	3.004	228.5	2.04	27.965	-23.221
Sep	12 0600	270.0	0.8	270.8	40.00	208.83	0.076	239.4	2.884	237.0	1.61	27.955	-25.408
Sep	13 0600	270.0	0.5	270.5	33.00	172.29	0.066	236.1	2.709	242.7	1.26	27.932	-27.212
Sep	14 0600	270.0	0.1	270.1	33.00	172.29	0.062	241.6	2.638	246.9	1.04	27.905	-29.011
Sep	15 0600	270.0	-0.1	269.9	20.00	104.42	0.062	247.0	2.671	247.8	1.01	27.876	-30.121
Sep	16 0600	270.0	-0.5	269.5	27.00	140.96	0.063	253.9	2.727	249.0	0.96	27.847	-31.605
Sep	17 0600	270.0	-1.2	268.8	39.00	203.61	0.061	256.2	2.649	253.9	0.68	27.803	-33.726
Sep	18 0600	270.0	-2.2	267.8	50.00	261.04	0.054	251.5	2.456	261.8	0.26	27.718	-36.423
Sep	19 0600	270.0	-3.4	266.6	55.00	287.14	0.046	253.9	2.407	268.8	0.09	27.580	-39.373
Sep	20 0600	270.0	-3.9	266.1	25.00	130.52	0.043	257.5	2.484	269.4	0.14	27.498	-40.731
Sep	20 1800	281.2	-4.0	277.2	3.80	19.84	0.042	258.0	2.490	269.5	0.33	27.516	-40.949
Sep	21 0600	292.5	-4.1	288.4	3.80	19.84	0.041	258.3	2.473	269.8	0.79	27.566	-41.159
Sep	22 0600	270.0	-4.4	265.6	13.00	67.87	0.040	260.6	2.492	270.5	0.21	27.517	-41.879
Sep	23 0600	292.5	-5.2	287.3	30.00	156.62	0.033	264.6	2.368	274.2	0.53	27.935	-43.427
Sep	23 1800	315.0	-5.6	309.4	13.50	70.48	0.029	263.7	2.270	276.3	1.24	28.334	-43.998
Sep	24 0100	326.2	-5.9	320.3	8.10	42.29	0.027	261.6	2.158	277.7	1.46	28.623	-44.283
Sep	24 0600	270.0	-6.0	264.0	5.40	28.19	0.027	262.5	2.159	278.0	0.52	28.597	-44.575
Sep	25 0600	270.0	-6.3	263.7	14.50	75.70	0.028	265.9	2.188	278.7	0.57	28.527	-45.370
Sep	25 1800	270.0	-6.4	263.6	4.50	23.49	0.028	267.0	2.197	278.9	0.58	28.505	-45.621
Sep	26 0600	225.0	-6.3	218.7	17.00	88.75	0.033	277.2	2.426	278.0	2.09	27.887	-46.206
Sep	26 1500	270.0	-6.5	263.5	11.60	60.56	0.033	281.0	2.450	278.8	0.65	27.830	-46.828
Sep	27 0600	225.0	-6.4	218.6	19.40	101.28	0.039	290.3	2.646	278.6	2.29	27.129	-47.495
Sep	28 0600	270.0	-6.7	263.3	24.00	125.30	0.038	289.4	2.618	281.0	0.80	27.017	-48.783
Sep	29 0600	270.0	-6.9	263.1	14.00	73.09	0.038	286.6	2.562	282.4	0.85	26.954	-49.547
Sep	30 0600	270.0	-7.2	262.8	24.00	125.30	0.037	281.9	2.486	284.7	0.93	26.829	-50.832
Oct	01 0600	270.0	-7.3	262.7	14.00	73.09	0.037	279.1	2.451	286.1	0.97	26.759	-51.594
Oct	02 0600	270.0	-7.4	262.6	25.00	130.52	0.038	280.0	2.419	288.4	1.05	26.621	-52.930
Oct	03 0600	270.0	-7.4	262.6	39.00	203.61	0.044	295.0	2.476	289.8	1.13	26.405	-54.992
Oct	04 0600	270.0	-7.3	262.7	47.00	245.38	0.053	307.8	2.652	289.8	1.21	26.152	-57.466
Oct	05 0600	270.0	-6.2	263.8	63.00	328.91	0.059	308.8	2.636	291.4	1.22	25.833	-60.768
Oct	06 0600	270.0	-4.5	265.5	57.00	297.58	0.061	308.6	2.755	292.8	1.27	25.623	-63.764
Oct	07 0600	270.0	-3.3	266.7	40.00	208.83	0.060	306.3	2.884	293.5	1.30	25.534	-65.882
Oct	07 1700	270.0	-2.7	267.3	23.00	120.08	0.061	304.6	2.952	292.5	1.26	25.495	-67.095
Oct	08 0600	247.5	-2.5	245.0	5.00	26.10	0.062	304.7	2.988	292.0	2.18	25.419	-67.358
Oct	09 0600	247.5	-2.0	245.5	11.80	61.61	0.065	304.9	3.052	290.8	2.17	25.231	-67.966
Oct	09 1200	225.0	-1.9	223.1	5.00	26.10	0.067	305.4	3.082	290.2	2.84	25.070	-68.159
Oct	10 0600	281.2	-1.5	279.7	15.50	80.92	0.069	307.0	3.037	288.8	0.48	25.217	-68.986
Oct	11 0600	247.5	0.1	247.6	59.00	308.03	0.096	303.7	3.326	280.1	1.79	24.171	-71.847
Oct	11 1800	247.5	0.6	248.1	27.00	140.96	0.102	304.2	3.365	276.3	1.59	23.723	-73.169
Oct	12 0200	270.0	0.9	270.9	22.50	117.47	0.088	316.7	3.241	274.8	0.22	23.752	-74.342

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 04f: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.020
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.4	272.4	9.00	46.99	0.084	221.8	4.435	209.2	3.96	27.900	-17.527
Sep	10	0600	270.0	2.0	272.0	45.00	234.94	0.090	231.6	3.692	215.2	3.09	27.878	-19.970
Sep	11	0600	270.0	1.3	271.3	60.00	313.25	0.090	243.4	3.053	228.6	2.07	27.883	-23.222
Sep	12	0600	270.0	0.8	270.8	40.00	208.83	0.075	239.6	2.928	237.0	1.63	27.859	-25.408
Sep	13	0600	270.0	0.5	270.5	33.00	172.29	0.065	235.7	2.752	242.6	1.29	27.825	-27.210
Sep	14	0600	270.0	0.1	270.1	33.00	172.29	0.061	241.1	2.684	246.9	1.06	27.790	-29.006
Sep	15	0600	270.0	-0.1	269.9	20.00	104.42	0.061	246.6	2.732	247.7	1.03	27.753	-30.114
Sep	16	0600	270.0	-0.4	269.6	27.00	140.96	0.063	253.6	2.801	248.9	0.99	27.715	-31.596
Sep	17	0600	270.0	-1.1	268.9	39.00	203.61	0.062	256.2	2.733	253.6	0.72	27.664	-33.714
Sep	18	0600	270.0	-2.1	267.9	50.00	261.04	0.055	252.3	2.536	261.5	0.28	27.578	-36.409
Sep	19	0600	270.0	-3.3	266.7	55.00	287.14	0.048	254.9	2.477	268.4	0.07	27.442	-39.356
Sep	20	0600	270.0	-3.8	266.2	25.00	130.52	0.045	258.3	2.542	268.9	0.12	27.362	-40.714
Sep	20	1800	281.2	-3.9	277.3	3.80	19.84	0.044	258.7	2.545	269.1	0.36	27.379	-40.932
Sep	21	0600	292.5	-4.0	288.5	3.80	19.84	0.043	259.0	2.530	269.4	0.83	27.426	-41.143
Sep	22	0600	270.0	-4.3	265.7	13.00	67.87	0.042	261.2	2.547	270.1	0.20	27.379	-41.865
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.035	265.4	2.423	273.7	0.57	27.794	-43.413
Sep	23	1800	315.0	-5.6	309.4	13.50	70.48	0.031	265.0	2.327	275.9	1.29	28.189	-43.987
Sep	24	0100	326.2	-5.8	320.4	8.10	42.29	0.028	263.3	2.217	277.1	1.52	28.477	-44.275
Sep	24	0600	270.0	-5.9	264.1	5.40	28.19	0.028	264.2	2.217	277.5	0.51	28.452	-44.567
Sep	25	0600	270.0	-6.2	263.8	14.50	75.70	0.029	267.8	2.244	278.2	0.56	28.386	-45.362
Sep	25	1800	270.0	-6.3	263.7	4.50	23.49	0.029	269.0	2.252	278.4	0.57	28.367	-45.614
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.034	278.7	2.465	277.6	2.11	27.756	-46.206
Sep	26	1500	270.0	-6.5	263.5	11.60	60.56	0.034	282.6	2.488	278.5	0.64	27.701	-46.829
Sep	27	0600	225.0	-6.4	218.6	19.40	101.28	0.040	291.5	2.688	278.4	2.32	27.009	-47.506
Sep	28	0600	270.0	-6.7	263.3	24.00	125.30	0.040	289.7	2.651	280.8	0.80	26.904	-48.794
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.039	287.0	2.598	282.2	0.85	26.849	-49.559
Sep	30	0600	270.0	-7.2	262.8	24.00	125.30	0.039	282.4	2.523	284.4	0.93	26.732	-50.845
Oct	01	0600	270.0	-7.2	262.8	14.00	73.09	0.039	279.7	2.491	285.9	0.98	26.670	-51.609
Oct	02	0600	270.0	-7.3	262.7	25.00	130.52	0.039	280.5	2.443	288.2	1.05	26.542	-52.946
Oct	03	0600	270.0	-7.3	262.7	39.00	203.61	0.045	295.2	2.497	289.6	1.13	26.336	-55.008
Oct	04	0600	270.0	-7.3	262.7	47.00	245.38	0.053	308.0	2.670	289.6	1.21	26.094	-57.483
Oct	05	0600	270.0	-6.2	263.8	63.00	328.91	0.059	309.0	2.647	291.3	1.22	25.787	-60.786
Oct	06	0600	270.0	-4.5	265.5	57.00	297.58	0.061	308.8	2.764	292.8	1.27	25.589	-63.782
Oct	07	0600	270.0	-3.3	266.7	40.00	208.83	0.061	306.3	2.890	293.5	1.30	25.511	-65.899
Oct	07	1700	270.0	-2.7	267.3	23.00	120.08	0.061	304.6	2.959	292.5	1.26	25.477	-67.113
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.062	304.7	2.991	291.9	2.18	25.409	-67.380
Oct	09	0600	247.5	-2.0	245.5	11.80	61.61	0.065	304.9	3.051	290.8	2.17	25.236	-67.997
Oct	09	1200	225.0	-1.9	223.1	5.00	26.10	0.067	305.5	3.079	290.2	2.84	25.080	-68.194
Oct	10	0600	281.2	-1.5	279.7	15.50	80.92	0.068	307.0	3.032	288.8	0.48	25.230	-69.020
Oct	11	0600	247.5	0.1	247.6	59.00	308.03	0.096	303.8	3.315	280.1	1.78	24.198	-71.888
Oct	11	1800	247.5	0.6	248.1	27.00	140.96	0.101	305.0	3.351	276.3	1.59	23.756	-73.213
Oct	12	0200	270.0	0.9	270.9	22.50	117.47	0.089	318.0	3.226	274.8	0.22	23.786	-74.385

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 05d: Course: Columbus log from Marden
Positioning: spherical trigonometry
Computation interval: from log, generally 24 hours
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Position	
Mon	Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.5	272.5	9.00	46.99	0.079	222.3	4.499	207.9	4.06	27.922	-17.524
Sep	10	0600	270.0	2.4	272.4	45.00	234.94	0.084	221.8	4.425	209.1	3.95	27.897	-19.963
Sep	11	0600	270.0	2.0	272.0	60.00	313.25	0.090	231.8	3.665	215.3	3.06	27.882	-23.211
Sep	12	0600	270.0	1.3	271.3	40.00	208.83	0.090	243.4	3.048	228.8	2.06	27.853	-25.405
Sep	13	0600	270.0	0.8	270.8	33.00	172.29	0.075	239.5	2.926	237.1	1.63	27.816	-27.213
Sep	14	0600	270.0	0.5	270.5	33.00	172.29	0.064	235.7	2.752	242.7	1.28	27.775	-29.010
Sep	15	0600	270.0	0.1	270.1	20.00	104.42	0.061	241.3	2.690	246.9	1.06	27.739	-30.117
Sep	16	0600	270.0	-0.1	269.9	27.00	140.96	0.061	246.7	2.742	247.7	1.04	27.698	-31.598
Sep	17	0600	270.0	-0.4	269.6	39.00	203.61	0.063	253.7	2.809	249.0	0.99	27.644	-33.717
Sep	18	0600	270.0	-1.1	268.9	50.00	261.04	0.062	256.1	2.741	253.7	0.72	27.551	-36.416
Sep	19	0600	270.0	-2.1	267.9	55.00	287.14	0.055	252.3	2.549	261.7	0.28	27.408	-39.367
Sep	20	0600	270.0	-3.3	266.7	25.00	130.52	0.048	255.3	2.495	268.3	0.07	27.325	-40.726
Sep	20	1800	281.2	-3.8	277.4	3.80	19.84	0.045	258.6	2.560	268.9	0.38	27.344	-40.944
Sep	21	0600	292.5	-3.9	288.6	3.80	19.84	0.044	258.9	2.560	269.0	0.86	27.398	-41.154
Sep	22	0600	270.0	-4.0	266.0	13.00	67.87	0.043	259.2	2.540	269.4	0.15	27.347	-41.876
Sep	23	0600	292.5	-4.3	288.2	30.00	156.62	0.042	261.5	2.560	270.0	0.80	27.773	-43.424
Sep	23	1800	315.0	-5.2	309.8	13.50	70.48	0.035	265.6	2.432	273.8	1.43	28.176	-43.991
Sep	24	0100	326.2	-5.6	320.6	8.10	42.29	0.031	265.1	2.328	275.9	1.64	28.469	-44.273
Sep	24	0600	270.0	-5.8	264.2	5.40	28.19	0.028	263.2	2.211	277.2	0.50	28.443	-44.565
Sep	25	0600	270.0	-5.9	264.1	14.50	75.70	0.028	264.5	2.222	277.5	0.52	28.368	-45.359
Sep	25	1800	270.0	-6.2	263.8	4.50	23.49	0.029	268.1	2.252	278.2	0.56	28.345	-45.611
Sep	26	0600	225.0	-6.3	218.7	17.00	88.75	0.029	269.3	2.261	278.4	1.95	27.720	-46.187
Sep	26	1500	270.0	-6.2	263.8	11.60	60.56	0.034	279.4	2.483	277.5	0.59	27.662	-46.809
Sep	27	0600	225.0	-6.5	218.5	19.40	101.28	0.035	283.2	2.501	278.4	2.16	26.952	-47.464
Sep	28	0600	270.0	-6.3	263.7	24.00	125.30	0.041	291.8	2.717	278.2	0.68	26.834	-48.751
Sep	29	0600	270.0	-6.6	263.4	14.00	73.09	0.041	289.9	2.674	280.6	0.79	26.767	-49.515
Sep	30	0600	270.0	-6.8	263.2	24.00	125.30	0.040	287.3	2.630	281.9	0.85	26.636	-50.800
Oct	01	0600	270.0	-7.1	262.9	14.00	73.09	0.040	283.0	2.565	284.1	0.93	26.560	-51.563
Oct	02	0600	270.0	-7.2	262.8	25.00	130.52	0.040	280.5	2.543	285.5	0.98	26.413	-52.896
Oct	03	0600	270.0	-7.2	262.8	39.00	203.61	0.041	281.3	2.487	287.8	1.05	26.174	-54.954
Oct	04	0600	270.0	-7.2	262.8	47.00	245.38	0.046	295.6	2.547	289.0	1.13	25.891	-57.423
Oct	05	0600	270.0	-7.1	262.9	63.00	328.91	0.055	308.3	2.732	289.0	1.20	25.514	-60.711
Oct	06	0600	270.0	-6.0	264.0	57.00	297.58	0.061	310.7	2.710	290.5	1.21	25.237	-63.692
Oct	07	0600	270.0	-4.2	265.8	40.00	208.83	0.063	311.0	2.845	291.9	1.25	25.116	-65.800
Oct	07	1700	270.0	-3.1	266.9	23.00	120.08	0.063	307.3	2.974	292.7	1.29	25.067	-67.009
Oct	08	0600	247.5	-2.4	245.1	5.00	26.10	0.064	304.8	3.080	291.8	2.24	24.983	-67.268
Oct	09	0600	247.5	-2.3	245.2	11.80	61.61	0.065	304.9	3.104	291.3	2.24	24.778	-67.868
Oct	09	1200	225.0	-1.9	223.1	5.00	26.10	0.067	304.8	3.163	290.2	2.91	24.614	-68.056
Oct	10	0600	281.2	-1.7	279.5	15.50	80.92	0.067	304.8	3.215	289.6	0.56	24.754	-68.881
Oct	11	0600	247.5	-1.4	246.1	59.00	308.03	0.070	306.9	3.173	288.2	2.12	23.641	-71.693
Oct	11	1800	247.5	0.1	247.6	27.00	140.96	0.116	300.5	3.506	279.0	1.83	23.176	-73.009
Oct	12	0200	270.0	0.6	270.6	22.50	117.47	0.110	297.0	3.546	275.1	0.28	23.195	-74.185

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 05e: Course: Marden casebook [Marden, 1986b]
Positioning: rhumbline
Computation interval: log period
Day lengthening: not used
Magnetic correction: van Bemmelen for 1500 ad.
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.000N 17.000W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Posiiton	
Mon	Da	Time	Mag	Var	True	League	Kmeter	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.5	272.5	9.00	46.99	0.079	222.2	4.500	207.9	4.07	27.918	-17.532
Sep	10	0600	270.0	2.4	272.4	45.00	234.94	0.084	221.8	4.426	209.2	3.95	27.915	-19.970
Sep	11	0600	270.0	2.0	272.0	60.00	313.25	0.089	231.8	3.654	215.3	3.06	27.937	-23.216
Sep	12	0600	270.0	1.3	271.3	40.00	208.83	0.089	243.0	3.014	228.8	2.03	27.925	-25.409
Sep	13	0600	270.0	0.8	270.8	33.00	172.29	0.075	239.3	2.892	237.1	1.61	27.900	-27.217
Sep	14	0600	270.0	0.5	270.5	33.00	172.29	0.065	236.0	2.718	242.8	1.26	27.871	-29.015
Sep	15	0600	270.0	0.1	270.1	20.00	104.42	0.062	241.6	2.652	247.0	1.04	27.839	-30.124
Sep	16	0600	270.0	-0.1	269.9	27.00	140.96	0.061	247.0	2.693	247.8	1.01	27.807	-31.605
Sep	17	0600	270.0	-0.5	269.5	39.00	203.61	0.063	254.0	2.748	249.0	0.96	27.768	-33.726
Sep	18	0600	270.0	-1.2	268.8	50.00	261.04	0.061	256.1	2.666	253.9	0.69	27.701	-36.426
Sep	19	0600	270.0	-2.2	267.8	55.00	287.14	0.054	251.5	2.465	262.0	0.25	27.587	-39.381
Sep	20	0600	270.0	-3.4	266.6	25.00	130.52	0.046	254.0	2.406	268.8	0.09	27.509	-40.740
Sep	21	0600	286.9	-3.9	283.0	7.50	39.16	0.043	257.5	2.482	269.4	0.58	27.574	-41.165
Sep	22	0600	270.0	-4.1	265.9	13.00	67.87	0.041	258.2	2.469	269.9	0.17	27.526	-41.886
Sep	23	0600	292.5	-4.4	288.1	30.00	156.62	0.040	260.7	2.489	270.6	0.75	27.950	-43.435
Sep	24	0600	315.0	-5.3	309.7	27.00	140.96	0.033	264.6	2.363	274.4	1.37	28.746	-44.581
Sep	25	0600	270.0	-6.1	263.9	14.50	75.70	0.026	260.7	2.101	278.6	0.53	28.676	-45.375
Sep	26	0600	270.0	-6.4	263.6	4.50	23.49	0.026	263.8	2.129	279.2	0.57	28.657	-45.638
Sep	26	1800	225.0	-6.5	218.5	17.00	88.75	0.027	264.8	2.136	279.4	1.87	28.038	-46.223
Sep	27	0600	270.0	-6.4	263.6	15.50	80.92	0.032	275.8	2.384	278.4	0.61	27.962	-47.055
Sep	27	1800	225.0	-6.7	218.3	15.50	80.92	0.032	280.3	2.406	279.5	2.11	27.401	-47.588
Sep	28	0600	270.0	-6.6	263.4	24.00	125.30	0.037	288.0	2.555	279.3	0.70	27.280	-48.862
Sep	29	0600	270.0	-6.9	263.1	14.00	73.09	0.036	286.9	2.525	281.8	0.81	27.218	-49.627
Sep	30	0600	270.0	-7.1	262.9	24.00	125.30	0.036	284.6	2.471	283.2	0.86	27.095	-50.914
Oct	01	0600	270.0	-7.4	262.6	14.00	73.09	0.035	280.1	2.380	285.6	0.93	27.024	-51.677
Oct	02	0600	270.0	-7.5	262.5	25.00	130.52	0.034	276.8	2.325	287.1	0.97	26.885	-53.012
Oct	03	0600	270.0	-7.5	262.5	39.00	203.61	0.035	278.4	2.334	289.5	1.06	26.661	-55.075
Oct	04	0600	270.0	-7.6	262.4	47.00	245.38	0.042	295.2	2.408	290.7	1.14	26.397	-57.552
Oct	05	0600	270.0	-7.5	262.5	63.00	328.91	0.052	307.7	2.580	290.6	1.22	26.050	-60.855
Oct	06	0600	270.0	-6.3	263.7	57.00	297.58	0.059	307.4	2.585	292.1	1.23	25.797	-63.851
Oct	07	0600	270.0	-4.5	265.5	40.00	208.83	0.060	307.4	2.728	293.4	1.28	25.690	-65.969
Oct	08	0600	270.0	-3.3	266.7	28.00	146.18	0.059	305.7	2.859	293.8	1.31	25.655	-67.466
Oct	09	0600	247.5	-2.5	245.0	11.80	61.61	0.060	304.5	2.933	292.2	2.15	25.469	-68.075
Oct	09	1200	225.0	-2.1	222.9	5.00	26.10	0.063	304.8	3.002	291.0	2.79	25.309	-68.269
Oct	10	0600	281.2	-1.9	279.3	15.50	80.92	0.065	305.4	3.029	290.4	0.58	25.453	-69.097
Oct	11	0600	247.5	-1.5	246.0	59.00	308.03	0.066	305.6	2.964	289.0	2.02	24.376	-71.939
Oct	11	1800	247.5	0.1	247.6	27.00	140.96	0.091	303.3	3.251	280.2	1.75	23.922	-73.258
Oct	12	0200	270.0	0.6	270.6	22.50	117.47	0.099	307.9	3.297	276.5	0.34	23.949	-74.435

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 06a: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: field from Columbus 1492 observations
Current field: autumnal
Wind field: autumnal Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

			Course			Distance		Current		Wind		Norm	Positon	
Mon	Da	Time	Mag	Var	True	League	Kmeter	m/s	dir	m/s	dir	Wind	lat	lon
Sep	09	0600	270.0	2.9	272.9	9.00	46.99	0.084	221.8	4.425	209.1	3.97	27.925	-17.526
Sep	10	0600	270.0	2.4	272.4	45.00	234.94	0.089	231.5	3.664	215.1	3.08	27.936	-19.969
Sep	11	0600	270.0	1.4	271.4	60.00	313.25	0.089	242.9	3.004	228.5	2.04	27.966	-23.222
Sep	12	0600	270.0	0.7	270.7	40.00	208.83	0.076	239.4	2.886	237.0	1.60	27.948	-25.409
Sep	13	0600	270.0	0.2	270.2	33.00	172.29	0.065	236.0	2.715	242.7	1.26	27.916	-27.213
Sep	14	0600	270.0	-0.3	269.7	33.00	172.29	0.062	241.5	2.649	246.9	1.03	27.876	-29.011
Sep	15	0600	270.0	-1.2	268.8	20.00	104.42	0.061	246.8	2.693	247.8	0.97	27.832	-30.120
Sep	16	0600	270.0	-2.3	267.7	27.00	140.96	0.063	253.7	2.772	249.0	0.89	27.767	-31.602
Sep	17	0600	270.0	-4.0	266.0	39.00	203.61	0.062	256.1	2.742	253.6	0.59	27.646	-33.718
Sep	18	0600	270.0	-5.6	264.4	50.00	261.04	0.056	253.1	2.619	261.2	0.15	27.428	-36.401
Sep	19	0600	270.0	-5.5	264.5	55.00	287.14	0.050	256.7	2.615	267.7	0.14	27.165	-39.334
Sep	20	0600	270.0	-5.3	264.7	25.00	130.52	0.048	259.9	2.678	268.1	0.16	27.048	-40.687
Sep	20	1800	281.2	-5.3	275.9	3.80	19.84	0.047	260.3	2.675	268.2	0.36	27.061	-40.907
Sep	21	0600	292.5	-5.3	287.2	3.80	19.84	0.046	260.6	2.658	268.5	0.85	27.107	-41.120
Sep	22	0600	270.0	-5.2	264.8	13.00	67.87	0.045	262.6	2.680	269.1	0.20	27.048	-41.841
Sep	23	0600	292.5	-5.2	287.3	30.00	156.62	0.038	267.1	2.556	272.6	0.65	27.455	-43.390
Sep	23	1800	315.0	-5.3	309.7	13.50	70.48	0.034	267.5	2.459	274.8	1.41	27.853	-43.961
Sep	24	0100	326.2	-5.3	320.9	8.10	42.29	0.031	266.5	2.350	276.1	1.66	28.144	-44.246
Sep	24	0600	270.0	-5.3	264.7	5.40	28.19	0.031	267.6	2.350	276.4	0.48	28.121	-44.537
Sep	25	0600	270.0	-5.3	264.7	14.50	75.70	0.031	271.6	2.374	277.3	0.52	28.064	-45.333
Sep	25	1800	270.0	-5.4	264.6	4.50	23.49	0.032	272.9	2.380	277.5	0.53	28.047	-45.585
Sep	26	0600	225.0	-5.4	219.6	17.00	88.75	0.036	281.8	2.559	276.8	2.15	27.442	-46.184
Sep	26	1500	270.0	-5.5	264.5	11.60	60.56	0.037	285.9	2.580	277.8	0.59	27.395	-46.806
Sep	27	0600	225.0	-5.5	219.5	19.40	101.28	0.044	291.9	2.794	277.7	2.38	26.710	-47.490
Sep	28	0600	270.0	-5.6	264.4	24.00	125.30	0.044	290.3	2.737	280.1	0.74	26.622	-48.780
Sep	29	0600	270.0	-5.6	264.4	14.00	73.09	0.043	287.8	2.695	281.5	0.79	26.577	-49.547
Sep	30	0600	270.0	-5.6	264.4	24.00	125.30	0.042	283.7	2.623	283.7	0.87	26.485	-50.835
Oct	01	0600	270.0	-5.6	264.4	14.00	73.09	0.042	281.1	2.598	285.2	0.92	26.438	-51.602
Oct	02	0600	270.0	-5.6	264.4	25.00	130.52	0.042	281.7	2.508	287.6	0.99	26.340	-52.941
Oct	03	0600	270.0	-5.5	264.5	39.00	203.61	0.046	295.6	2.543	289.1	1.06	26.184	-55.008
Oct	04	0600	270.0	-5.2	264.8	47.00	245.38	0.054	308.1	2.696	289.3	1.12	26.011	-57.489
Oct	05	0600	270.0	-4.0	266.0	63.00	328.91	0.059	308.9	2.642	291.3	1.13	25.810	-60.802
Oct	06	0600	270.0	-2.3	267.7	57.00	297.58	0.061	308.1	2.740	293.1	1.18	25.703	-63.807
Oct	07	0600	270.0	-1.2	268.8	40.00	208.83	0.059	305.8	2.854	293.8	1.21	25.687	-65.929
Oct	07	1700	270.0	-0.6	269.4	23.00	120.08	0.059	304.5	2.899	292.8	1.16	25.688	-67.145
Oct	08	0600	247.5	-0.5	247.0	5.00	26.10	0.060	304.5	2.937	292.3	2.09	25.622	-67.413
Oct	09	0600	247.5	-0.3	247.2	11.80	61.61	0.063	304.7	3.007	291.1	2.09	25.454	-68.031
Oct	09	1200	225.0	-0.3	224.7	5.00	26.10	0.065	305.2	3.030	290.5	2.76	25.300	-68.231
Oct	10	0600	281.2	-0.1	281.1	15.50	80.92	0.066	306.0	2.962	289.1	0.42	25.464	-69.054
Oct	11	0600	247.5	0.0	247.5	59.00	308.03	0.086	302.6	3.216	280.6	1.75	24.450	-71.933
Oct	11	1800	247.5	0.0	247.5	27.00	140.96	0.099	308.3	3.275	276.9	1.61	23.996	-73.253
Oct	12	0200	270.0	0.0	270.0	22.50	117.47	0.092	322.2	3.159	275.3	0.29	24.014	-74.427

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

Case 06b: Course: Columbus log from Marden
Positioning: rhumbline
Computation interval: 30 minutes
Day lengthening: not used
Magnetic correction: Defense Mapping Agency for 1980 ad.
Current field: not used
Wind field: not used Leeway wind factor: 0.014
Starting latitude/Longitude position: 28.005N 16.992W
Starting Day/time: 08 0300

		Course			Distance		Current		Wind		Norm	Position	
Mon Da	Time	Mag	Var	True	League	km	m/s	dir	m/s	dir	Wind	lat	lon
Sep 09	0600	270.0	-10.9	259.1	9.00	46.99	0.000	0.0	0.000	0.0	0.00	27.926	-17.461
Sep 10	0600	270.0	-11.8	258.2	45.00	234.94	0.000	0.0	0.000	0.0	0.00	27.510	-19.799
Sep 11	0600	270.0	-13.1	256.9	60.00	313.25	0.000	0.0	0.000	0.0	0.00	26.901	-22.888
Sep 12	0600	270.0	-13.8	256.2	40.00	208.83	0.000	0.0	0.000	0.0	0.00	26.464	-24.929
Sep 13	0600	270.0	-14.5	255.5	33.00	172.29	0.000	0.0	0.000	0.0	0.00	26.086	-26.603
Sep 14	0600	270.0	-15.1	254.9	33.00	172.29	0.000	0.0	0.000	0.0	0.00	25.691	-28.266
Sep 15	0600	270.0	-15.4	254.6	20.00	104.42	0.000	0.0	0.000	0.0	0.00	25.444	-29.269
Sep 16	0600	270.0	-15.9	254.1	27.00	140.96	0.000	0.0	0.000	0.0	0.00	25.103	-30.618
Sep 17	0600	270.0	-16.4	253.6	39.00	203.61	0.000	0.0	0.000	0.0	0.00	24.593	-32.554
Sep 18	0600	270.0	-17.1	252.9	50.00	261.04	0.000	0.0	0.000	0.0	0.00	23.918	-35.017
Sep 19	0600	270.0	-17.6	252.4	55.00	287.14	0.000	0.0	0.000	0.0	0.00	23.148	-37.702
Sep 20	0600	270.0	-17.9	252.1	25.00	130.52	0.000	0.0	0.000	0.0	0.00	22.790	-38.914
Sep 20	1800	281.2	-17.9	263.3	3.80	19.84	0.000	0.0	0.000	0.0	0.00	22.769	-39.106
Sep 21	0600	292.5	-17.9	274.6	3.80	19.84	0.000	0.0	0.000	0.0	0.00	22.784	-39.299
Sep 22	0600	270.0	-18.0	252.0	13.00	67.87	0.000	0.0	0.000	0.0	0.00	22.596	-39.928
Sep 23	0600	292.5	-18.1	274.4	30.00	156.62	0.000	0.0	0.000	0.0	0.00	22.704	-41.448
Sep 23	1800	315.0	-18.2	296.8	13.50	70.48	0.000	0.0	0.000	0.0	0.00	22.990	-42.061
Sep 24	0100	326.2	-18.2	308.0	8.10	42.29	0.000	0.0	0.000	0.0	0.00	23.224	-42.386
Sep 24	0600	270.0	-18.3	251.7	5.40	28.19	0.000	0.0	0.000	0.0	0.00	23.144	-42.648
Sep 25	0600	270.0	-18.3	251.7	14.50	75.70	0.000	0.0	0.000	0.0	0.00	22.931	-43.349
Sep 25	1800	270.0	-18.3	251.7	4.50	23.49	0.000	0.0	0.000	0.0	0.00	22.865	-43.567
Sep 26	0600	225.0	-18.2	206.8	17.00	88.75	0.000	0.0	0.000	0.0	0.00	22.153	-43.955
Sep 26	1500	270.0	-18.2	251.8	11.60	60.56	0.000	0.0	0.000	0.0	0.00	21.983	-44.513
Sep 27	0600	225.0	-18.2	206.8	19.40	101.28	0.000	0.0	0.000	0.0	0.00	21.171	-44.954
Sep 28	0600	270.0	-18.1	251.9	24.00	125.30	0.000	0.0	0.000	0.0	0.00	20.820	-46.100
Sep 29	0600	270.0	-18.0	252.0	14.00	73.09	0.000	0.0	0.000	0.0	0.00	20.617	-46.767
Sep 30	0600	270.0	-17.8	252.2	24.00	125.30	0.000	0.0	0.000	0.0	0.00	20.271	-47.910
Oct 01	0600	270.0	-17.7	252.3	14.00	73.09	0.000	0.0	0.000	0.0	0.00	20.070	-48.576
Oct 02	0600	270.0	-17.5	252.5	25.00	130.52	0.000	0.0	0.000	0.0	0.00	19.716	-49.765
Oct 03	0600	270.0	-17.1	252.9	39.00	203.61	0.000	0.0	0.000	0.0	0.00	19.172	-51.617
Oct 04	0600	270.0	-16.5	253.5	47.00	245.38	0.000	0.0	0.000	0.0	0.00	18.534	-53.846
Oct 05	0600	270.0	-15.2	254.8	63.00	328.91	0.000	0.0	0.000	0.0	0.00	17.725	-56.836
Oct 06	0600	270.0	-13.7	256.3	57.00	297.58	0.000	0.0	0.000	0.0	0.00	17.058	-59.548
Oct 07	0600	270.0	-12.5	257.5	40.00	208.83	0.000	0.0	0.000	0.0	0.00	16.634	-61.457
Oct 07	1700	270.0	-11.8	258.2	23.00	120.08	0.000	0.0	0.000	0.0	0.00	16.407	-62.557
Oct 08	0600	247.5	-11.6	235.9	5.00	26.10	0.000	0.0	0.000	0.0	0.00	16.275	-62.760
Oct 09	0600	247.5	-11.3	236.2	11.80	61.61	0.000	0.0	0.000	0.0	0.00	15.967	-63.238
Oct 09	1200	225.0	-11.1	213.9	5.00	26.10	0.000	0.0	0.000	0.0	0.00	15.772	-63.373
Oct 10	0600	281.2	-10.7	270.5	15.50	80.92	0.000	0.0	0.000	0.0	0.00	15.775	-64.128
Oct 11	0600	247.5	-8.7	238.8	59.00	308.03	0.000	0.0	0.000	0.0	0.00	14.301	-66.553
Oct 11	1800	247.5	-7.8	239.7	27.00	140.96	0.000	0.0	0.000	0.0	0.00	13.654	-67.674
Oct 12	0200	270.0	-7.0	263.0	22.50	117.47	0.000	0.0	0.000	0.0	0.00	13.518	-68.751

Notes: Magnetic field measurements are in degrees; westward deflections are negative.
All positions are in degrees, north and east being positive from the equator and Greenwich Meridian respectively.
Normal winds are in meters/sec.
All dates are as recorded in Columbus's log, Julian calendar.

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16. Abstract (Limit: 200 words)

An article in the November 1986 *National Geographic* magazine examined the question of Columbus's first landfall in the Americas. The author, Luis Marden, was the first to quantitatively include the effects of the winds and currents in reconstructing the transoceanic portion of the voyage. There seemed, however, to be two major weaknesses in his analysis. First, the leeway effect on the ship by the wind was ignored for that portion of the voyage west of 40W, the whole second half of the voyage. Second, currents from pilot charts were used with the corresponding speed determined by the prevailing current. We sought to reanalyze the track using the leeway effect for the whole transatlantic track and using more appropriate average vector velocities of the current. Using climatological winds and currents we found the island of San Salvador (Watling Island) to be the most likely site of the first landfall of Columbus. This paper discusses the effects of wind, current, leeway, and magnetic variation on the determination of the landfall.

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1. Voyage of Christopher Columbus
2. Discovery of San Salvador
3. Historical Currents and Winds

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